Special Programs
Graduate School, U S D A
Washington, D. C.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

August 1975

PREFACE

This manual presents information, data, and guidelines for planning, designing, and operating agricultural waste management systems. It is intended for use by field offices of the U.S. Soil Conservation Service (SCS). It supplements but does not supersede national or state standards, specifications, or requirements of SCS as they pertain to various conservation practices.

Every effort has been made to render this manual as accurate, useful, and nearly complete as possible. For this reason, there is some overlapping of materials in the various chapters. It should be noted too that research and field experience continually provide improvements in basic data and concepts for agricultural waste management. Because of such rapidly changing technology and also in order to provide data to the field as quickly as possible, further refinement of the manual has not been attempted at this time.

It is expected that state or regional additions will be made to various chapters of the text to conform with local, state, and regional waste management standards, laws, rules, and regulations, as well as experience.

This manual was developed under the guidance of John T. Phelan, former director, and Neil F. Bogner, director, Engineering Division, SCS, Washington, D.C.; and prepared by the Agricultural Waste Management Field Manual Committee, consisting of the following members:

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CHAPTER 1. LAWS, RULES, AND REGULATIONS

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CHAPTER 1. LAWS, RULES, AND REGULATIONS

1. FEDERAL RESPONSIBILITY

The Environmental Protection Agency (EPA) is the federal regulatory agency responsible for controlling air and water pollution, drinking water quality, solid waste management, pesticide uses, environmental radiation, and noise. The broad legislative authorities given EPA to deal with air and water pollution and solid waste management have special interest for SCS.

AIR

The federal government's authority began with the Air Pollution Act of 1955 authorizing federally funded air pollution research. Later legislation included the Motor Vehicle Pollution Control Act of 1965, the Air Quality Act of 1967, and the Clean Air Act of 1970. The Clean Air Act provides for uniform air quality standards and control of emissions from existing facilities. Also, it prohibits construction of new facilities that violate or interfere with federal or state regulations for air quality standards.

WATER

Federal legislation for water quality began with the Rivers and Harbors Act of 1886 and 1889. A national policy for prevention, control, and abatement of water pollution was established in 1948 with the Federal Water Pollution Control Act. This act was amended in 1956. The federal role in water pollution control was enlarged by the Water Quality Act of 1965, the Clear Water Restoration Act of 1966, and the Water Quality Improvement Act of 1970.

The most far-reaching legislation came with Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972, the objective of which is to restore the chemical, physical, and biological integrity of the nation's water. To achieve this objective, the law sets a national goal of no discharge of any pollutants into navigable waters of the United States by 1985.

The 1972 law's basic requirement is that operators of point source discharges, such as those from industrial and municipal facilities, feedlots, and other discrete significant sources, must obtain a permit specifying allowable amounts and constituents of effluents and a schedule for achieving compliance

States are required to develop a comprehensive planning process for water quality management. Plans must include not only controls for point source pollution but also controls for diffuse land runoff and other nonpoint (accumulative) source pollution.

National Pollutant Discharge Elimination System (NPDES)

Procedures to be followed by EPA in processing and issuing permits under NPDES were published in the Federal Register on May 22, 1973, and became effective immediately. Many categories and classes of agricultural and silvicultural operations are excluded from the permit system. These exclusions apply to smaller, insignificant discharges, which include minor irrigation return-flow discharges and runoff from fields and from crop and forest lands.

To help determine who must apply for a permit, the specific instructions for Short Form B--Agriculture include a listing of types and numbers of animals held for 30 days or more annually in confined animal production facilities:

Slaughter steers and heifers	1,000 or more
Dairy cattle	700 or more
Swine over 55 lb	2,500 or more
Sheep	10,000 or more
Turkeys (open lots only)	55,000 or more
Laying hens or broilers (constant flow watering)	100,000 or more
Laying hens and broilers (liquid manure handling system)	30,000 or more
Ducks	5,000 or more
Equivalent combinations of these (See instructions.)	

Certain commercial fish production facilities also are subject to permit requirements. These include fish raceways or similar structures where discharge to receiving waters occurs for 30 or more days a year and facilities that contain, grow, or hold species of nonnative fish and other aquatic animal life. Specifically excluded are closed ponds that discharge only during annual harvest or periods of excess runoff and caged facilities in lakes, estuaries, or marine waters.

A system that has irrigation return flow through a point source such as a pipe, channel, or other discrete conveyance, whether owned or operated by an individual, company, or organization, is subject to permit requirements if it provides irrigation service to land areas of 3,000 or more cultivated acres.

Further, the owner or operator of any point source that contributes significantly to pollution is subject to permit requirements, regardless of the size of the operation.

General instructions for applying for a permit under NPDES and a copy of Short Form B--Agriculture (EPA Form 7550-7[7-73]) are included at the end of this chapter. Short Form B is used to provide information for irrigation activities and fish production facilities as well as animal facilities.

Feedlot Effluent Guidelines and Standards

Proposed effluent guidelines and standards applicable to feedlots of all sizes were published by EPA in the Federal Register on September 7, 1973. They would have required that, except for duck feedlots, there

be by July 1, 1977, no discharge to navigable waters of waste water or runoff except runoff resulting from more than a 10-year, 24-hour storm. This is a rainfall event with a probable recurrence interval of once in 10 years. These guidelines and standards would have required also that for all feedlots there be by July 1, 1983, no discharge of waste water or runoff except runoff resulting from more than a 25-year, 24-hour storm (rainfall event with probable recurrence interval of once in 25 years).

After public review and the consideration of resulting comments, however, final effluent guidelines and standards for feedlots of the same size as those covered under NPDES were published February 14, 1974, and became effective April 15, 1974. Guidelines and standards for smaller lots are still under evaluation by EPA and will be published at a future date.

The effluent guidelines and standards for large feedlots published February 14, 1974, are summarized as follows:

Existing Feedlots, Except for Ducks (by July 1, 1977).--The pertinent section of the rules and regulations is headed "Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best practicable control technology currently available."

No process waste water pollutants shall be discharged, except that ". . . Process waste pollutants in the overflow may be discharged to navigable waters whenever rainfall events, either chronic or catastrophic, cause an overflow of process waste water from a facility designed, constructed and operated to contain all process generated waste waters plus the runoff from a 10-year, 24-hour rainfall event for the location of the point source." (The term "process waste water" includes any precipitation that comes in contact with wastes; "process generated waste water" excludes precipitation.)

Existing Feedlots for Ducks (by July 1, 1977).--"Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best practicable control technology currently available."

Concentrations of 5-day biochemical oxygen demand (BOD_5)[1/] in effluents shall not exceed 3.66 lb (1.66 kg) per 1,000 ducks (maximum for any one day) and 2.00 lb (0.91 kg) per 1,000 ducks (average of daily values for 30 consecutive days). Concentrations of fecal coliform in effluents are not to exceed most probable number (MPN) of 400/100 ml at any time.

Existing Feedlots, Including Ducks (by July 1, 1983).--"Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best available technology economically achievable."

No process waste water pollutants shall be discharged, except that " . . . Process waste pollutants in the overflow may be discharged to

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[1/] BOD and other terms and abbreviations are explained in detail in chapter 4 and the glossary.

navigable waters whenever rainfall events, either chronic or catastrophic, cause an overflow of process waste water from a facility designed, constructed and operated to contain all process generated waste waters plus the runoff from a 25-year, 24-hour rainfall event for the location of the point source."

New Sources, Including Ducks (Effective April 15, 1974).--"Standards of performance for new sources."

No process waste water pollutants shall be discharged, except that " . . . Process waste pollutants in the overflow may be discharged to navigable waters whenever rainfall events, either chronic or catastrophic, cause an overflow of process waste water from a facility designed, constructed and operated to contain all process generated waste waters plus the runoff from a 25-year, 24-hour rainfall event for the location of the point source."

SOLID WASTE

Congress in 1965 enacted the Solid Waste Disposal Act. This act was the first federal legislation dealing with the effects on the environment of solid waste disposal. It resulted mostly in money grants to state governments for further disbursement through different state agencies for waste disposal programs being initiated.

In 1970 Congress amended the 1965 act with the Resources Recovery Act, which officially recognized the potential economic benefits of recovering some portion of discarded refuse. This legislation also directed new grant programs to urban areas with solid waste problems.

The Rural Development Act of 1972 (Public Law 92-419), when implemented, provides for U.S. Department of Agriculture (USDA) assistance in solid waste disposal as part of Public Law 566 and Resource Conservation and Development (RC&D) projects.

2. STATE RESPONSIBILITY

Laws of all states must meet the minimum requirements of the federal laws dealing with air and water quality and disposal of solid wastes. Many states already have such laws, and in some cases the state laws are more stringent than the federal laws. In the absence or neglect of state laws, EPA assumes enforcement.

All work in which SCS assists must meet the minimum requirements of federal, state, and local laws and regulations. Land owners or operators are responsible for obtaining required approvals and permits and for operating facilities in accordance with these laws and regulations.

3. APPENDIX: SHORT FORM B AND GENERAL INSTRUCTIONS

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
APPLICATION FOR PERMIT TO DISCHARGE
SHORT FORM B–AGRICULTURE

GENERAL INSTRUCTIONS

The Federal Water Pollution Control Act, as amended by Public Law 92-500, enacted October 18, 1972, prohibits any person from discharging pollutants into a waterway (e.g., streams, rivers, lakes) from a point source (see definitions below), unless his discharge is authorized by a permit issued either by the U.S. Environmental Protection Agency or by an approved State agency. (See "Procedures for Filing.")

Requirements

If you have a discharge or discharges, such as that described in the first paragraph of these instructions, you must complete one of the following forms to apply for a discharge permit. The forms differ by types of discharges as indicated below:

Short Form A–Municipal Wastewater Dischargers.
Short Form B–Agriculture.
Short Form C–Manufacturing Establishments and Mining.
Short Form D–Services, Wholesale and Retail Trade, and All Other Commercial Establishments, Including Vessels, Not Engaged in Manufacturing or Agriculture.

If your business or activity involves production of both raw products and ready-for-market products, you may be required to complete two of the above forms. For example, if you produce a raw product, such as milk, and, on the same site, process the raw milk into cheese, you must complete Form B–Agriculture, and Form C–Manufacturing and Mining.

If the discharge is from a Federal facility's treatment plant receiving more than 50 percent domestic waste (based on the dry weather flow rate), complete and submit form A.

If the discharge is from a sewage treatment process which is not from a municipal, agricultural, or industrial facility (e.g., housing subdivision, school), complete and submit form D.

Exclusions

You are not required to obtain a permit for the following types of waste discharges:

1. Sewage discharged from vessels (e.g., ships); or
2. Water, gas, and other materials injected into a well to facilitate production of oil or gas, or water derived in association with oil or gas production and disposed of in a well, where authorized by the State in which the well is located; or
3. Dredged or fill material; or
4. Discharges from properly functioning marine engines; or
5. Those discharges conveyed directly to a publicly or privately owned waste treatment facility (however, discharges originating from publicly or privately owned waste treatment facilities are not excluded); or

> Note.–Municipal and manufacturing dischargers that believe they are exempt due to item 5 are requested to complete certain items and return the form (see "Procedures for Filing").

6. Most discharges from separate storm sewers. Discharges from storm sewers which receive industrial, municipal, and/or agricultural wastes, or which are considered by EPA or a State to be significant contributors to pollution, are not excluded.

Procedures for Filing

If you have any questions as to whether or not you need a permit under this program, contact your State water pollution control agency or the nearest regional office of the U.S. Environmental Protection Agency. A list of EPA regional offices is given in table 1.

Copies of all forms are available at State water pollution control agencies and at all Environmental Protection Agency regional offices.

Data submitted on these forms are to be used as a basis for issuing discharge permits. Depending on the adequacy and nature of the data submitted, you may be called upon for additional information before a permit is granted.

Complete the appropriate form(s) for your operation, being sure that each item is considered and the required data submitted. Give the answer which most nearly applies to you and your operation. If an item does not apply, please enter, in the appropriate place, "Not Applicable" or "NA" to show that the item was given consideration. Most of the items on the form require the checking of one or more of several possible answers.

If the application is to be sent to the Environmental Protection Agency, there is an application fee of $10. This fee, in the form of a check or money order made payable to the Environmental Protection Agency, should be mailed with the original of the application form to the EPA regional office having jurisdiction over the State in which the discharge is located.

If the State in which the discharge is located has a federally approved permit program, the application should instead be sent to the State agency administering the program. You will be informed as to the amount of the application fee, if any, and the address to which the application and fee should be sent.

Agencies and instrumentalities of Federal, State, or local governments will not be required to pay an application fee to the Environmental Protection Agency.

Anyone who applied to the U.S. Army Corps of Engineers for a discharge permit under the Refuse Act of 1899 need not reapply for a permit for the same discharge, unless it is substantially changed in nature, volume, or frequency; application must also be made for any other discharges not covered by the Refuse Act.

Applications for proposed discharges must apply at least 180 days before the date the discharge is due to begin, unless a delay is granted by the approved State agency or by EPA.

Signature on Application

The person who signs the application form will often be the applicant himself. When another person signs on behalf of the applicant, his title or relationship to the applicant should be shown in the space provided. In all cases, the person signing the form should be authorized to do so by the applicant. An application submitted by a corporation must be signed by a principal executive officer of at least the level of vice president, or his duly authorized representative, if such representative is responsible for the overall operation of the facility from which the discharge(s) described in the form originate. In the case of a partnership or a sole proprietorship, the application must be signed by a general partner or the proprietor, respectively. In the case of a municipal, State, Federal, or other public facility, the application must be signed by

TABLE 1.—*Addresses of EPA regional offices and States within their jurisdiction*

Region	Address and phone	States
I.	Regional Administrator, Region I, Environmental Protection Agency, John F. Kennedy Federal Bldg., Room 2303, Boston, Mass. 02203. Attention: Permits Branch. 617-223-7210.	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.
II.	Regional Administrator, Region II, Environmental Protection Agency, 26 Federal Plaza, Room 908, New York, N.Y. 10007. Attention: Permits Branch. 212-264-9895.	New Jersey, New York, Virgin Islands, Puerto Rico.
III.	Regional Administrator, Region III, Environmental Protection Agency, Curtis Bldg., Sixth and Walnut Sts., Philadelphia, Pa. 19106. Attention: Permits Branch. 215-597-9966.	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia.
IV.	Regional Administrator, Region IV, Environmental Protection Agency, 1421 Peachtree St., N.E., Atlanta, Ga. 30309. Attention: Permits Branch. 404-526-3971.	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee.
V.	Regional Administrator, Region V, Environmental Protection Agency, 1 North Wacker Dr., Chicago, Ill. 60606. Attention: Permits Branch. 312-353-1472.	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin.
VI.	Regional Administrator, Region VI, Environmental Protection Agency, 1600 Patterson St., Suite 1100, Dallas, Tex. 79201. Attention: Permits Branch. 214-749-1983.	Arkansas, Louisiana, New Mexico, Oklahoma, Texas.
VII.	Regional Administrator, Region VII, Environmental Protection Agency, 1735 Baltimore Ave., Kansas City, Mo. 64108. Attention: Permits Branch. 816-374-5955.	Iowa, Kansas, Missouri, Nebraska.
VIII.	Regional Administrator, Region VIII, Environmental Protection Agency, 1860 Lincoln St., Suite 900, Denver, Colo. B0203. Attention: Permits Branch, 303-837-4901.	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming.
IX.	Regional Administrator, Region IX, Environmental Protection Agency, 100 California St., San Francisco, Calif. 94111. Attention: Permits Branch. 415-556-3450.	Arizona, California, Hawaii, Nevada, Guam, American Samoa, Trust Territories.
X.	Regional Administrator, Region X, Environmental Protection Agency, 1200 Sixth Ave., Seattle, Wash. 98101. Attention: Permits Branch. 206-442-1213.	Alaska, Idaho, Oregon, Washington.

either a principal executive officer, ranking elected official, or other duly authorized employee.

Use of Information

All information contained in this application will, upon request, be made available to the public for inspection and copying. A separate sheet entitled "Confidential Answers" must be used to set out information which is considered by the applicant to be methods and processes entitled to protection as trade secrets. The information must clearly indicate the item number to which it applies. Confidential treatment can be considered only for that information for which a specific written request of confidentiality has been made on the attached sheet. However, in no event will identification of the contents, volume, and frequency of a discharge be recognized as confidential or privileged information, except in certain cases involving the national security.

Definitions

1. A "person" is an individual, partnership, corporation, association, State, municipality, commission, other political subdivision of a State, or any interstate body.

2. The term "pollutant" includes solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

3. A "point source" is any discernible, confined and discrete conveyance including but not limited to a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal-feeding operation, or vessel or other floating craft from which pollutants are or may be discharged.

4. A "discharge of pollutant" or a "discharge of pollutants" means any addition of any pollutant to the waters of the United States from any point source; any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.

5. A "discharge," when used without qualification, includes a "discharge of pollutant" and a "discharge of pollutants" (see above).

6. The term "municipality" means a city, town, borough, county, parish, district, association, or other public body created by or pursuant to State law and having jurisdiction over disposal of sewage, industrial wastes, or other wastes, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved areawide waste treatment management agency.

SPECIFIC INSTRUCTIONS

Who Must Apply

The owner or operator of any facility as described below or any facility, regardless of size, which the Regional Administrator or Director of the State water pollution control agency or interstate agency considers to be a significant pollution problem. Final determination on the need for a permit will be based upon a review of the application and, in many instances, site visits.

1. *Animal production facilities.*

A. A facility that has or may have a discharge, providing a confined area for feeding or holding animals, but not including areas

used for growing crops or vegetation for animal feed, which holds, or during the previous 12 months held for a total of 30 days or more, any of the following number of animals:

Types of animals	Number of animals
Slaughter and feeder cattle	1,000
Mature dairy cattle—milker and dry	700
All swine over 55 pounds	2,500
Sheep	10,000
Turkeys—in open lots	55,000
Ducks	5,000
Laying hens and broilers:	
Facilities with continuous overflow	100,000
Facilities with liquid manure handling systems*	30,000

*Any system where the manure is collected, stored, or transported utilizing liquid manure conveyance by gravity flow or pumping system.

B. Any facility that has or may have a discharge, wherein animals are held, or during the previous 12 months were held for a total of 30 days or more, in such combination that the sum of the following animals multiplied by the following multipliers equals or exceeds 1,000:

Slaughter and feeder cattle	1.0
Mature dairy cattle	1.4
Swine over 55 pounds	0.4
Sheep	0.1

Example:

Number of animals	Times	Multiplier	Equals
Slaughter and feeder cattle . . . 600	X	1.0	600
Mature dairy cattle 200	X	1.4	280
Swine over 55 pounds 500	X	0.4	200
Total			1,080

Since the total exceeds 1,000, a permit application must be submitted.

C. Owners or operators, whether individuals, partnerships, or corporations, with more than one confined animal production facility located on adjacent or nearby properties, where:

(1) such facilities utilize a common waste control system or disposal area, and

(2) the total number of animals or combination of animals in the individual operations exceeds the above animal limits.

2. *Fish and aquatic animal production facilities.*

A. Facilities such as hatcheries, fish farms, or other facilities which contain, grow, or hold aquatic animals in ponds, raceways or other similar structures for purposes of production and from which there is or will be a discharge for any 30 days or more per year. Closed ponds which discharge less than 30 days per year or only during periods of excess runoff are excluded from these requirements except as provided in 2B and 4 below. In addition, facilities which produce less than 20,000 pounds of aquatic animals per year are excluded from filing an application, except as provided for in 2B and 4 below.

B. Any facility which contains, grows, or holds any species of fish or other aquatic animal life nonnative to the United States, from which there is a discharge to a navigable water at any time. The nonnative species of fish are as defined in Special Publication No. 6 of the American Fisheries Society, entitled, "A List of Common and Scientific Names of Fishes from the United States and Canada." (For purposes of this application, carp, brown trout, and goldfish are not considered to be nonnative species.)

3. *Irrigation activities.*—Discharges of irrigation return flow (such as tailwater, tile drainage, surfaced ground water flow or bypass water), operated by public or private organizations or individuals if: (1) there is a point source of discharge (e.g., a pipe, ditch, or other defined or discrete conveyance, whether natural or artificial) and; (2) the return flow is from land areas of 3,000 or more contiguous acres, or 3,000 noncontiguous acres which use the same drainage system. It is the individual or organization who actually has control of or responsibility for the discharge of irrigation return flow who must apply for the permit. For example, if water is supplied by an organization but returned to navigable waters by an individual who has 3,000 or more acres under irrigation, it is the individual who must apply for a permit. On the other hand, if an irrigation organization supplies and controls the irrigation return flow discharged from a total of 3,000 or more acres to navigable waters, the organization must apply for a permit; an individual whose acreage is counted in the organization's total, even though the individual's acreage alone may be 3,000 acres or more, need not apply for a permit if the organization, and not the individual, controls the discharge of return flow.

4. *General agriculture activities.*—Any agricultural operation with any point source discharge, otherwise excluded from mandatory application filing requirements, which the EPA Regional Administrator or State or interstate agency identifies as a significant contributor of pollution.

5. *Voluntary filing.*—None of the above requirements preclude the voluntary filing of an NPDES application by the owner or operator of an agricultural or silvicultural activity.

Instructions for Individual Items

Section I—General.

Item 1. A. Give the name, as it is legally referred to, of the person, firm, public organization, or any other entity which owns or is directly responsible for the facility or activity described in this application. This may or may not be the same name as the facility or activity producing the discharge. Do not use colloquial names as a substitute for the official name.

B. Give the complete mailing address of the applicant's main office. This often will not be the same address used to designate the location of the facility or activity.

Item 2. Give the name, title, address, and telephone number of a person who is thoroughly familiar with the facts reported on the forms and can be contacted by reviewing offices if necessary.

Item 3. The facility is the distinct activity or installation, under the responsibility of the applicant, which produces or may produce one or more point sources of pollution. Name the facility as it is officially or legally referred to in order to distinguish it from similar entities in the same geographical area. Do not use colloquial names as a substitute for the official name. Check the appropriate box in item 3.B to indicate if the facility is publicly or privately owned or both. Check the box in item 3.C if this is a federally owned or operated facility. Give the actual location of the facility in item 3.D. If the area in which the facility is located uses the grid system (i.e., township, section, quarter, range) for specifying location, complete items 3.D.1 (a-f). If the grid system is not used, complete items 3.D.2 (a-c).

Item 4. Indicate whether the facility is existing (currently operating) or proposed (to be operating in the future).

Item 5. For an existing facility, give the date construction was completed for its current capacity. The expected completion date should be given if the facility is currently under construction or planned.

Item 6. Name the waterway(s) (e.g., stream, river, lake) at the point(s) of discharge. Use the name of the waterway by which it is usually designated on published maps of the area; if possible, refer to one of the map series published by the U.S. Geological Survey. When the discharge is to an unnamed tributary, please so state and give the name of the first body of water fed by that tributary that is named on the map, e.g., "*Unnamed* ditch to Vaughan Creek;" "*Unnamed* arroyo to Serpent River," where Serpent River is the first body of water reached by the discharge that is named on the map.

Item 7. Self-explanatory.

Item 8. Self-explanatory.

Item 9. Directions should use known landmarks and route numbers if possible.

Item 10. Self-explanatory.

Item 11. Check the appropriate box(es) to indicate the one or more types of agricultural operations which are being described in this application. Proceed to the appropriate section(s) according to the box(es) checked.

Section II–Animal confinement and feeding facilities.

Item 1. Give the largest number of each type of animal held by the facility for 30 days or more during the previous 12 months. If possible, use the same designations for the types of animals as was listed at the beginning of these instructions under "Who Must Apply."

Item 2. Give only the area used for the animal confinement or feeding facility. Do not include area used for growing or preparing feed.

Item 3. Give acres of land that are owned or leased by the facility for manure disposal.

Item 4. Indicate in 4.A whether the animals are entirely in the open, totally under roof, or partially under roof. Indicate in 4.C the percentage of the lot that is roofed versus that which is open.

Item 5. If the facility is planned to be expanded in the future, give the expected date for this expansion and the new total capacity by type and number of animals.

Section III–Fish and other aquatic animal production facilities.

Item 1. Give the month during which the maximum total weight of the combined species on hand occurs. For that month, list the type and average pounds of each species in the system. Fish names listed should be the proper, common, or scientific names as given in Special Publication No. 6 of the American Fisheries Society, "A List of Common and Scientific Names of Fishes from the United States and Canada."

Item 2. The above publication should also be used as the reference to determine whether or not a fish species is native to the United States, except that carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), and brown trout (*Salmo trutta*) are deemed native for purposes of this program.

Item 3. Self-explanatory.

Item 4. Self-explanatory.

Item 5. Provide the values for the parameters listed in the units specified. Samples should be representative of the month indicated in item 1. In order for the values to be representative, they should be based on at least a 24-hour composite sample. If grab samples were taken, values should represent a minimum of the average of 4 consecutive weeks. Analytical methods to be used and level of data reported are shown in table 2.

Item 6. Give the average number of pounds of food fed per day for the month listed in item 1 in which the maximum total weight of the combined species on hand occurs. Also, give the type of food utilized; i.e., specify moist pellets, dry pellets, offal, or other specific food type.

Section IV–Irrigation activities with point return flows.

Item 1. If return flows from the irrigation occur the year around, check the box provided in item 1.A. Otherwise, check the box(es) beside the month(s) listed under item 1.B to show when the flows occur.

Item 2. Give the acreage irrigated by each irrigation method.

Item 3. Give the total water diverted (total inflow) by this activity for irrigation from a basic source of supply, such as a river, reservoir, or well. Give the total water returned from point sources and discharged to surface waters (e.g., streams, rivers, lakes, etc.).

Item 4. Give the number of separate discrete points at which water is being diverted for irrigation purposes and the number of the return points.

TABLE 2.–*Chemical parameters: standard analytical methods (interim)*
[To be used with item 5, section III]

Parameter, units, and (code)	Method	References		
		Standard Methods 13th edition, 1971	A.S.T.M. Standards, Part 23, 1972	EPA Methods, 1971
Total suspended (nonfilterable) solids, milligrams per liter (00530)	Glass fiber filtration 103°-105° C.	p. 537		p. 278
Ammonia (as N), milligrams per liter (00610)	Distillation-nesslerization or automated phenolate.			p. 134, p. 141
BOD 5-day, milligrams per liter (00310)	Modified winkler or probe method.	p. 489	p. 618	p. 15

Note.–This table is to be used as a guide in reporting the data concerning each parameter. The first column, "Parameter, units, and (code)" indicates the preferred units for reporting data for a given parameter. The second column, "Method," lists the preferred analytical method for determining the required parameter values. The next three columns, "References," give the page numbers in standard reference works where a detailed description of the recommended analytical techniques given under "Method" can be found. These standard references are:

1. "Standard Methods for the Examination of Water and Wastewaters," 13th Edition, 1971, American Public Health Association, New York, N.Y. 10019.
2. "A.S.T.M. Standards," pt. 23, Water; Atmospheric Analysis, 1972, American Society for Testing and Materials, Philadelphia, Pa. 19103.
3. "EPA Methods for Chemical Analysis of Water and Wastes," April 1971, Environmental Protection Agency, Water Quality Office, Analytical Quality Control Laboratory, NERC, Cincinnati, Ohio 45268.

Copies of the publications are available from the above sources, or for review in the regional offices of the Environmental Protection Agency or the State water pollution control agency.

Data must be reported with an accuracy of *at least* two significant digits; i.e., values less than 1 must be reported *at least* to the nearest .01, values between 1 and 10 to the nearest 0.1, values between 10 and 100 to the nearest 1.0, and so forth.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
APPLICATION FOR PERMIT TO DISCHARGE
SHORT FORM B
Agriculture

To be completed by confined animal production facilities, fish farms, hatcheries, and preserves, and irrigation activities meeting size or other criteria described herein. Please print or type.

I. GENERAL

1. Name and address of applicant

   A. Legal name of applicant ______________________________

   B. Mailing address of applicant

      (1) Street, route, or P.O. box No. ______________________________

      (2) City or town ______________________________

      (3) County, parish, or borough ______________________________

      (4) State ______________________________ (5) Zip code ______________

   C. Telephone number __________ Area code ______________________ Number

2. Applicant's authorized agent

   A. Name ______________________________ B. Title ______________________

   C. Mailing address of agent

      (1) Street, route, or P.O. box No. ______________________________

      (2) City or town ______________________________

      (3) County, parish, or borough ______________________________

      (4) State ______________________________ (5) Zip code ______________

   D. Telephone number __________ Area code ______________________ Number

I certify that I am familiar with the information contained in the application and that to the best of my knowledge and belief such information is true, complete, and accurate.

______________________________ Printed name of person signing

______________________________ Title

______________________________ Signature of applicant

______________________________ Date application signed

18 U.S.C. section 1001 provides that:

Whoever, in any matter within the jurisdiction of any department or agency of the United States knowingly and willfully falsifies, conceals, or covers up by any trick, scheme, or device a material fact, or makes any false, fictitious, or fraudulent statement or representation, or makes or uses any false writing or document knowing same to contain false, fictitious, or fraudulent statement or entry, shall be fined not more than $10,000 or imprisoned not more than 5 years, or both.

3. Name, ownership, and physical location of facility

A. Name of facility

B. Ownership (check one)

(1) ☐ Public (2) ☐ Private (3) ☐ Both public and private

C. Check box if this is a federally owned and/or operated facility (for example, Black Creek National Fish Hatchery) ☐

D. Location (complete as applicable)

(1) Facility located where grid system is used

a. Township ________ b. Section ________

c. Quarter ________ d. Range ________

e. County ________ f. State ________

(2) Facility located where grid system is not used

a. City or town (as applicable) ________

b. County ________ c. State ________

FOR AGENCY USE	
CITY	COUNTY

4. Is this facility (check one) A. ☐ Existing? B. ☐ Proposed?

5. Date facility was (or will be) constructed ____/____
Month/Year

6. Receiving water(s) (e.g., stream, river, lake) ________
Name(s)

7. State water pollution control permits

A. Have you applied for a State water pollution control permit for this facility? (1) ☐ Yes (2) ☐ No

B. If a State water pollution control permit for this facility has been issued, give date of issue and permit number

(1) Date of issue ____/____/____
Month/Day/Year

(2) Permit number ________

8. Have you received, from any level of government, written notice of complaint pertaining to water pollution from this facility?

A. ☐ Yes B. ☐ No

9. Give directions to this facility from nearest town ________

____

____

____

____

10. **Attach a sketch, aerial photograph, or map of the existing or proposed facility and/or activity, with the following information marked (a Soil Conservation Service aerial photograph, or a U.S. Geological Survey Map, of the area involved is preferred).**

    A. Approximate overall dimensions of the facility

    B. Direction and location of surface drainage and other discharges from the facility

    C. General location of waterways (e.g., streams, rivers, lakes) in the area

    D. Location of area for manure disposal

    E. Direction and location of diversion points for irrigation activities

11. **Submission of this application is the result of (check as many as are applicable)**

    A ☐ Animal confinement facility

    B. ☐ Fish farm, hatchery, or preserve

    C. ☐ Irrigation return flow

    D. ☐ Other (specify)

> **If 11A was checked, complete items in, section II, "Animal Confinement and Feeding Facilities."**
> **If 11B was checked, complete items in section III, "Fish Farms, Hatcheries, and Preserves."**
> **If 11C was checked, complete items in section IV, "Irrigation Return Flows."**

II. ANIMAL CONFINEMENT AND FEEDING FACILITIES

1. **Largest number of animals held by confinement or feeding facilities at any one time in the previous 12 months. Give type and number of animals.**

TYPE OF ANIMAL	NUMBER OF ANIMALS
______________________	______________
______________________	______________
______________________	______________

2. **Approximate area used for animal confinement or feeding.** ____________ **acres**

3. **Approximate land available for manure disposal.** ________________ **acres**

4. A. Animals in this facility are (check one)

    (1) ☐ In open confinement

    (2) ☐ Housed under roof

    (3) ☐ Both in open confinement and housed under roof

    B. Percentage of animals housed under roof is _______ %

    C. If there is open confinement, has a run-off diversion been constructed to prevent surface run-off into the confinement area?

    (1) ☐ Yes (2) ☐ No

    D. If there are any housed animals at this facility, is there a liquid manure handling system used for manure management?

    (1) ☐ Yes (2) ☐ No If yes, is there a discharge to a waterway (e.g., stream, river, lake)?

    (3) ☐ Yes (4) ☐ No

5. **Do you anticipate expansion of this facility in the future?**

A. ☐ Yes B. ☐ No **If yes, complete the following statements.**

C. Date of future expansion ______/______
Month/Year

D. TYPE OF ANIMALS NUMBER OF ANIMALS

TYPE OF ANIMALS	NUMBER OF ANIMALS

III. FISH AND AQUATIC ANIMAL PRODUCTION FACILITIES

1. A. The maximum weight on hand of all species combined occurs during the month of ____________

B. List the type and average pounds of each species on hand during the month given in 1A

(1) SPECIES	(2) AVERAGE POUNDS UNDER PRODUCTION

2. **Do you produce, cultivate, or hold any nonnative (not native to the United States) species of fish or other aquatic animals?**

A. ☐ Yes B. ☐ No C. If yes, describe the procedures, such as disinfection or ultraviolet treatment, which you use to insure that parasites and pathogens do not escape into navigable waters.

____

____

____

3. **Is there a discharge for more than any 30 days per year?** A. ☐ Yes B. ☐ No
If yes, answer 4, 5, and 6.

4. **Facility designed for continuous cleaning?** A. ☐ Yes B. ☐ No
If no, state the averages to the following questions.

C. Facility cleaned ________ times per (1) ☐ day (2) ☐ month (check one).

D. Time required is _____ hours per cleaning.

5. **Discharge information.**

PARAMETER AND (CODE)	DAILY AVERAGE VALUE DURING NORMAL OPERATION	
Flow (00056)	____________	gallons per day
Total suspended solids (00530)	____________	milligrams per liter
Ammonia (00610)	____________	milligrams per liter
BOD 5-day (00310)	____________	milligrams per liter

6. Average pounds of food fed per day is A. ________ pounds of B. ________________________ (type of food).

IV. IRRIGATION ACTIVITIES WITH POINT RETURN FLOWS

1. A. Check here if discharge occurs all year. ☐

   B. If discharge does not occur all year, check the month(s) discharge occurs.

(1) ☐ January	(2) ☐ February	(3) ☐ March	(4) ☐ April
(5) ☐ May	(6) ☐ June	(7) ☐ July	(8) ☐ August
(9) ☐ September	(10) ☐ October	(11) ☐ November	(12) ☐ December

2. Estimate the total number of acres under irrigation using

   A. Surface method of irrigation ____________________ acres

   B. Sprinkler method of irrigation ____________________ acres

   C. Other methods of irrigation ____________________ acres

3. Estimate the total water

   A. Diverted for irrigation by this activity ______________ acre-feet/year

   B. Discharged to surface waters (e.g., lakes, streams, rivers) from irrigation return flow ______________ acre-feet/year

4. Estimate the number of separate points at which

   A. Water is diverted for irrigation ________

   B. Water is returned to surface waters ________

COMMENTS.

EPA Form 7550-7 (7-73)

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 2. WATER QUALITY

Compiled by Charles E. Fogg, sanitary engineer, SCS, Washington, D. C.

Contents

Tables

CHAPTER 2. WATER QUALITY

1. GENERAL

Water used for crop irrigation may have different quality requirements from that used for drinking, livestock, fish and other aquatic life, or recreation. However, public health and safety being paramount, the quality of water used for any specific purpose should also be considered in light of all other probable uses. Water should be free of impurities offensive to sight, smell, and taste. Table 2-2 is a summary of proposed EPA water quality criteria for various water uses.

DRINKING WATER STANDARDS

The first standards published in this country in 1914 were to protect the health of the traveling public. These standards were revised periodically by the U.S. Public Health Service (USPHS). They generally apply to all public water supplies.

The quality of water used for all purposes, including drinking, is now the responsibility of EPA although EPA continues to use the USPHS drinking water standards published in 1962 as the current federal drinking water standards (see table 2-1).

A low bacteria count is important for good quality of drinking water. Table 2-1 does not show all the bacteria counts required by federal, state, and local agencies. Procedures for required sampling, testing, reporting, and determining acceptable coliform counts for public water supply are complex and beyond the scope of this chapter. See the 1962 USPHS drinking water standards and consult local and state health agencies for details on the bacterial quality required in specific cases. See also USPHS drinking water standards for radioactivity limits.

The desirable limits listed in table 2-1 should not be exceeded if, in the judgment of the reporting agency and certifying authority, more suitable supplies can be located. Concentrations of substances in excess of the maximum limits listed constitute grounds for rejection of a water supply.

In December 1974 the Safe Drinking Water Act was signed into law. EPA has now proposed national drinking water standards, which are currently under review. The new standards, due to become effective in December 1976, expand the 1962 USPHS standards. Maximum limits are proposed for additional parameters such as mercury (0.002 mg/1) and certain pesticides in public drinking water. Turbidity standards proposed are more restrictive, 1 turbidity unit as desirable and a maximum limit of 5 units where turbidity does not interfere with disinfection and microbiological determinations.

Table 2-1.--Federal drinking water standards

Component	Desirable limit	Maximum limit
Physical:		
Turbidity (Jackson turbidity units) ...	5 units	---
Color (platinum-cobalt units)	15 units	---
Threshold odor No.	3	---
Chemical:	mg/l	mg/l
Alkyl benzene sulfonate (ABS)	0.5	---
Arsenic	.01	0.05
Barium	---	1.0
Cadmium	---	.01
Chloride	250	---
Chromium (Cr^{+6})	---	.05
Copper	1	---
Cyanide	.01	.2
Carbon chloroform extract (CCE)	.2	---
Fluoride (limit varies with annual average of maximum daily air temperature)		
50.3° - 53.7° F	1.2 (0.9-1.7)	1/ 2.4
53.8° - 58.3° F	1.1 (.8-1.5)	1/ 2.2
58.4° - 63.8° F	1.0 (.8-1.3)	1/ 2.0
63.9° - 70.6° F	.9 (.7-1.2)	1/ 1.8
70.7° - 79.2° F	.8 (.7-1.0)	1/ 1.6
79.3° - 90.5° F	.7 (.6- .8)	1/ 1.4
Iron	.3	---
Lead	---	.05
Manganese	.05	---
Nitrate (NO_3)	2/ 45	---
Phenols	.001	---
Selenium	---	.01
Silver	---	.05
Sulfate (SO_4)	250	---
Total dissolved solids	500	---
Zinc	5	---

1/ Concentrations of fluoride greater than twice the optimum constitute grounds for rejection of the supply.

2/ Public should be warned of water known to have a nitrate content in excess of 45 mg/l.

Table 2-2.--Tabular summary of numerical criteria

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)	Recreational Waters
pH	4.5-9.0	--	6.0-9.0	6.0-9.0	5.0-9.0	6.5-8.5	Acceptable - 6.5-8.3 Must be - 5.0-9.0
Alkalinity	--	--	75% natural level	30-130 mg/l	No limit*	--	--
Acidity	--	--	Addition of acids unacceptable	--	No limit	--	--
BOD	No limit	--	--	--	--	--	--
Al	5.0 mg/l 20.0 mg/l (20 yrs.)	5.0 mg/l	--	--	--	1/100 (0.01) 96-hr. LC_{50} 1.5 mg/l 1/10 LD_{50}	--
NH_3	--	--	1/20 (0.05) LC_{50} 0.02 mg/l	--	0.5 mg/l	0.4 mg/l	--
Sb	--	--	--	--	--	1/50 (0.02) 96-hr. LC_{50} 0.2 mg/l	--
As	0.10 mg/l 2.0 mg/l (20 yrs.)	0.2 mg/l	--	--	0.1 mg/l	1/100 (0.01) 96-hr. LC_{50} 0.05 mg/l	--
Ba	--	--	--	--	1.0 mg/l	1/20 (0.05) LD_{50} 1.0 mg/l	--
Be	0.1 mg/l 0.5 mg/l (20 yrs.)	No limit	--	--	--	1/100 (0.01) 96-hr. LC_{50} 1.5 mg/l	
Bi	--	--	--	--	--	No limit	--
B	0.75mg/l Sen. 1.0mg/l Semi-Tol. 2.0mg/l Tol.	5.0 mg/l	--	--	1.0 mg/l	1/10 (0.1) 96-hr. LC_{50}	--
Br	--	--	--	--	--	0.1 mg/l (free) 100 mg/l (ionic)	--

* "No limit", where it appears in this table, refers to constituents that were addressed but for which it was indicated that insufficient data existed for prescribing limits.

Table 2-2.--Tabular summary of numerical criteria--Continued

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)	Recreational Waters
HCO_3	No limit	--	--	--	--	--	--
Cd	0.01 mg/l 0.05 mg/l (20 yrs.)	50 ug/l	0.03 mg/l hard H_2O 0.004 mg/l soft H_2O	--	0.01 mg/l	1/100 (0.01)* 96-hr. LC_{50} 0.01 mg/l	--
Cl (free)	No limit	--	0.003 mg/l 0.05 mg/l (30 min.)	--	--	1/10 (0.1) 96-hr. LC_{50} 0.01 mg/l	--
Cl_2 (Chloride	No limit	--	--	--	250 mg/l	--	--
Cr	0.1 mg/l 1.0 mg/l (20 yrs.)	1.0 mg/l	0.03 mg/l	--	0.05 mg/l	1/100 (0.01) 96-hr. LC_{50} 0.1 mg/l	--
Co	0.05 mg/l 5.0 mg/l (20 yrs.)	1.0 mg/l	--	--	--	--	--
Cu	0.20 mg/l 5.0 mg/l	0.5 mg/l	1/10 (0.1) 96-hr. LC_{50}	--	1 mg/l	1/100 (0.01) 96-hr. LC_{50} 0.05 mg/l	--
(CN)	--	--	1/20 (0.05) 96-hr. LC_{50}	--	0.2 mg/l	1/10 (0.1) 96-hr. LC_{50} 0.01 mg/l	--
F	2.0 mg/l 1.0 mg/l (Sandy soil) 15.0 mg/l (20 yrs.)	2.0 mg/l	--	--	--	1/10 (0.1) 96-hr. LC_{50} 1.5 mg/l	--
H_2S	--	--	See sulfides	--	--	1/10 (0.1) 96-hr. LC_{50} 0.01 mg/l	--
Fe	5.0 mg/l 20.0 mg/l (20 yrs.)	No limit	--	--	0.3 mg/l	0.3 mg/l	--
Pb	5.0 mg/l 10.0 mg/l	0.1 mg/l	0.03 mg/l	--	0.05 mg/l	1/50 (0.02) 96-hr. LC_{50} 0.01 LD_{50}	--
Li	2.5 mg/l 0.075 mg/l	--	--	--	--	0.01 LD_{50} 24-hr. max. 0.05 mg/l	--

* If copper or zinc is present >1 mg/l, then AF = 0.001 LC_{50}

Table 2-2.--Tabular summary of numerical criteria--Continued

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)	Recreational Waters
Mn	0.20 mg/l 10.0 mg/l (20 yrs.)	No limit	--	--	0.05 mg/l	1/50 (0.02) 96-hr. LC_{50} 0.01 mg/l	--
Hg Inorganic	--	1.0 ug/l	0.2 ug/l Tot. conc. 0.05 ug/l Avg. conc. 0.5 ug/g Body burden Conc. Tot. Hg	0.5 ug/g in fish	0.002 mg/l Total	1/100 (0.01) 96-hr. LC_{50} 0.1 mg/l	--
Hg Organic	--	--	0.2 ug/l Tot. conc. 0.05 ug/l Avg. conc. 0.5 ug/g Body burden Conc. Tot. Hg	--	--	--	--
Mo	0.01 mg/l 0.05 mg/l	No limit	--	--	--	1/20 (0.05) 96-hr. LC_{50}	--
Ni	0.2 mg/l 2.0 mg/l (20 yrs.)	--	1/50 (0.02) 96-hr. LC_{50}	--	--	1/50 (0.02) 96-hr. LC_{50} 0.1 mg/l	--
(NO_3)	No limit	100 mg/l Combined (NO_3) & (NO_2)	--	--	10 mg/l	--	--
(NO_2)	--	10 mg/l	--	--	1 mg/l	--	--
P	--	--	--	--	No limit	1/100 (0.01) 96-hr. LC_{50} 0.1 ug/l	25 ug/l Lakes & res. 50 ug/l At confluence 100 ug/l Streams
Se	0.02 mg/l	0.05 mg/l	--	--	0.01 mg/l	1/100 (0.01) 96-hr. LC_{50} 0.01 mg/l	--
Na	No limit	--	--	--	No limit	--	--
Ag	--	--	--	--	0.05 mg/l	1/20 (0.05) 96-hr. LC_{50} 5.0 ug/l	--

Table 2-2.--Tabular summary of numerical criteria--Continued

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)	Recreational Waters
Tl	--	--	--	--	--	1/20 (0.05) 96-hr. LC_{50} 0.1 mg/l	--
U	--	--	--	--	--	1/100 (0.01) 96-hr. LC_{50} 0.5 mg/l	--
V	--	0.1 mg/l	--	--	--	1/20 (0.05) 96-hr. LC_{50}	--
Zn	--	25 mg/l	3/1000 (0.003) 96-hr. LC_{50}	--	5 mg/l	1/100 (0.01) 96-hr. LC_{50} 0.1 mg/l	--
Viruses	--	--	--	--	No limit	--	--
Micro-Organisms	--	5000 coli-forms/100 ml* 20,000/100ml**	--	2000/100 ml	10,000/100 ml	--	--
Fecal Coliforms	1000/100 ml	1000/100 ml* 4000/100 ml**	--	2000/100 ml	2000/100 ml	--	2000/100 ml avg. 4000/100 ml max. log mean 2n 200/100 ml <10% samples in 30-days to exceed 400/100 ml
Dissolved Solids (tot)	2000-5000 mg/l (Tolerant) 500-1000 mg/l (Sensitive)	--	Bioassays	--	No limit	--	--
Hardness	--	--	(See T.D.S.)	--	No limit	--	--
Suspended & Settleable Solids	No limit	--	80 mg/l	--	--	--	--
Temperature	No limit	--	See Text	(minimized) maintain natural pattern	not to detract from potability	2.0(3.6F)9-5 1.0(1.8F)6-8	86 F

* Average of a minimum of 2 samples per month
** Individual sample

Table 2-2.--Tabular summary of numerical criteria--Continued

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)	Recreational Waters
Toxic Algae	--	Heavy growth of blue-green not acceptable	--	No limit	--	--	--
Botulism	--	--	--	Minimizes factors which promote disease	--	--	--
Pesticides	--	See Public Water Stnds.	1/100 (0.01) 96-hr. LC_{50} Those for which no toxicity data available. See also Tables 1&2	--	--	1/100 (0.01) 96-hr. LC_{50}	--
Dalapon	0.2 ug/1	--	--	--	Silvex 0.03	--	--
TCA	0.2 ug/1	--	--	--	2,4,5-T 0.002	--	--
2,4-D	0.1 ug/1	--	--	--	0.02 ug/1	--	--
Insecticides	No limit	--	--	DDT 1 mg/kg wet weight	Table 5 Organophosphates 0.1 mg/1	--	--
Turbidity	--	--	$<$10% change in C.P.	--	No limit	--	Clarity - 4 ft. Seccchi
Carbon Adsorbable	--	--	--	--	0.3 mg/1 CCE 1.5 CAE	--	--
Foaming Agents	--	--	--	--	0.5 mg/1 (ABS)	--	--
NTA	--	--	--	--	No limit	--	--
Phenols	--	--	--	--	1 ug/1	--	--
Color	--	--	Comp. pt. not changed by $>$10%	--	75 platinum-cobalt units	--	--

Table 2-2.--Tabular summary of numerical criteria--Continued

Constituent	Agriculture (Irrigation)	Agriculture (Livestock)	Freshwater (Aquatic Life)	Freshwater (Wildlife)	Freshwater (Public Supply)	Marine Water (Aquatic Life)	Recreational Waters
Radio-activity	See Federal Drinking Water Standards	See Federal Drinking Water Standards	See Federal Drinking Water Standards	--	See Federal Drinking Water Standards	See Federal Drinking Water Standards	--
Salinity	--	3000 mg soluble salts/1	--	No rapid fluctuation	--	--	--
D.O.	--	--	See Table Section V	--	No limit saturation preferred	6.0 mg/1	--
Sulfate	--	--	--	--	250 mg/1	--	--
Sulfides	--	--	0.002 mg/1	--	--	--	--
Detergents	--	--	1/20 (0.05) (LAS) 96-hr. LC_{50} 0.2 mg/1 max.	--	--	--	--
Oils	--	--	No visible oil 1/20 (0.05) 96-hr. LD_{50} Hexane extractable sediments 1000 mg/kg	No visible floating oils	--	No film or odor No tainting of fish No onshore oil deposit	--
Phthalate Esters	--	--	0.3 ug/1	--	No limit	--	--
PCB's	--	--	0.002 ug/1 (in water) 0.5 ug/g (in tissue)	No increase	No limit	--	--
Tainting Substances	--	--	Tables 3&4	--	--	--	--
Odor	--	--	--	--	Free	--	--
Light	--	--	--	<10% change in C.P.	--	--	--

EPA WATER QUALITY CRITERIA

Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972, requires EPA to publish water quality criteria. Notice of publication of proposed water quality criteria was included in the Federal Register, October 26, 1973.

The proposed criteria are for water for irrigation and livestock, water for recreation and pleasure, marine water for aquatic life, and fresh water for wildlife, aquatic life, and public intake. These criteria are based in part on information in the National Technical Advisory Committee (NTAC) report on Water Quality Criteria (1968). The major source of information, however, is the National Academy of Sciences (NAS) Water Quality Criteria of 1972.

Comments on the proposed EPA water quality criteria were received through June 1974. Publication of final criteria is expected in the spring of 1975.

Table 2-2 tabulates the numerical criteria included in the EPA publication. This table is reproduced directly from appendix B of that publication and provides a comparison of water quality criteria for the various uses listed above. More detailed criteria and their rationale are given in the publication, which is available at EPA regional offices and state water pollution control agencies.

Table 2-2 does not list the quality required for water for farmstead uses--drinking, cooking, cleaning equipment used for processing milk and produce--but this water should meet federal drinking water standards.

Table 2-3 lists limits (1973) for certain insecticides not included specifically in table 2-2.

Table 2-3.--Recommended limits (1973) for chlorinated hydrocarbon insecticides in public raw water supply

Compound	Recommended limit 1/
	mg/1
Aldrin	0.001
Chlordane	2/ .003
DDT	.05
Dieldrin	.001
Endrin	.0005
Heptachlor	3/ .0001
Heptachlor epoxide	.0001
Lindane	2/ .005
Methoxychlor	2/ 1.0
Toxaphene	2/ .005

1/ Assume average daily intake of water of 2 liters.
2/ Adjusted for organoleptic effects.
3/ Adjusted for interconversion to H. epoxide.

OTHER WATER QUALITY REQUIREMENTS

Many industries have special water quality requirements to maintain quality of their products or to get satisfactory results from their processes and equipment.

For bottled beverages, fine chemicals, canned goods, processed milk, ice, packed meat, edible oils, and for laundering and for printing and dyeing of textiles, water must be of good bacteriological quality--clear, colorless, tasteless, relatively soft, and free from iron, manganese, hydrogen sulfide, and organic matter.

Laundries, electroplating plants, milk plants, ice plants, and textile mills require soft water. On the other hand, breweries, distilleries, and bakeries need relatively hard water.

Pulp and paper mills, tanneries, oil refineries, and steel mills often have quality needs somewhat less demanding than those for domestic water. Yet high quality paper needs very high quality water.

In actual practice, each individual enterprise has its own particular water quality needs. Consult industry representatives, textbooks, and other references for the needs of specific industries.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 3. MUNICIPAL WASTE WATER TREATMENT

Compiled by Charles E. Fogg, sanitary engineer, SCS, Washington, D.C.

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CHAPTER 3. MUNICIPAL WASTE WATER TREATMENT

1. GENERAL

This chapter is intended to provide familiarity with treatment of municipal waste water rather than a basis for design.

Municipal waste water normally includes waterborne wastes from households, called domestic sewage, and from commercial and industrial establishments, called trade or industrial wastes. Occasionally, storm water is included and the wastes are then called combined sewage. This occurs in older municipal systems that still use combined storm and sanitary sewers. The complex of collection, treatment, and disposal facilities is called a sewerage system.

Types of treatment for municipal waste water are basically physical, chemical, or biological. Physical treatment includes removal of solids from waste water by screening, skimming, and sedimentation. Chemical processes are used to flocculate and precipitate suspended solids (SS) and dissolved solids (DS), increase settling, and remove selected contaminants from waste water. Additional colloidal and dissolved matter is converted into settleable solids with biological treatment.

Degrees of treatment are commonly expressed as primary, secondary, or tertiary (also called advanced), depending on the relative amount of BOD and other pollutants removed in the process.

2. PRIMARY TREATMENT

The first unit operation in waste water treatment normally is screening. The screening unit may be a rack of parallel bars, rods, or wires or a screen of wire mesh or perforated plates. This screening process removes the larger solids and floating material from the waste water stream.

Screening is usually followed by sedimentation (separation by gravity of suspended particles that are heavier than water). The first sedimentation device is commonly a grit chamber, in which grit, sand, and gravel separate from the waste water and organic matter passes through. The next sedimentation device is a primary settling basin, in which organic and other particulate matter settle.

The waste water after screening and primary settling is often referred to as primary effluent. Primary treatment normally removes 25 to 40 percent of the BOD_5 in the raw sewage. Until recently, many communities chlorinated this effluent and discharged it to receiving waters. Current laws and regulations, however, require additional treatment before discharge.

3. SECONDARY TREATMENT

In secondary treatment, following primary treatment, the effluent from the primary settling basin is given further biological or chemical treatment, or both, by a number of processes. Tertiary treatment is often intermixed with secondary treatment processes.

BIOLOGICAL TREATMENT

The objectives of biological treatment are to coagulate and remove the nonsettleable colloidal solids and to degrade organic matter. Microorganisms such as bacteria, algae, and protozoa consume soluble food. They use organic matter as a source of energy, and convert finely divided suspended solids and dissolved matter into gelatinlike substances that flocculate and precipitate from the waste water.

Biological treatment is basically aerobic or anaerobic, depending on the availability of free oxygen and the kinds of micro-organisms used. Some treatment facilities are facultative, in which both aerobic and anaerobic micro-organisms function. This situation is more common in stabilization ponds or lagoons with aerobic conditions near the surface and anaerobic conditions near the bottom.

AEROBIC WASTE TREATMENT

Aerobic micro-organisms are used in the activated sludge process and in facilities such as trickling filters, aerated lagoons, and natural aerobic stabilization ponds.

Activated Sludge Process

The first step for turning waste into activated sludge is directing effluent from the primary settling basin to a large tank called a reactor. Air is then forced through the liquid by diffused or mechanical aeration, and the biological mass called activated sludge builds up. As the waste water becomes stabilized, additional biological solids are added to the mass. These solids are then separated in a secondary settling basin or tank. A portion of the separated solids is recycled to the reactor to keep biological activity at a maximum, and the remainder are removed for further processing.

Trickling Filter Process

In the trickling filter process, the waste water after primary settling is sprinkled over a bed of stones or other highly permeable medium. Biological solids form and attach to the filtering medium as the waste water trickles through. Organic material in the waste water is degraded by micro-organisms on the medium. An underdrain system collects the treated effluent and biological solids as they are detached. The underdrain also helps provide air to maintain aerobic conditions within the 3 to 8 feet of filter bed. The underdrain discharges to a secondary settling basin within which solids are separated from the effluent and removed.

Other Aerobic Processes

Other aerobic waste treatment processes include aerated and natural (photosynthetic) lagoons or stabilization ponds. An aerated lagoon functions about the same as the activated sludge process except that part of the biological mass is not recycled. Oxygen is supplied by mechanical aerators floating on the surface or by compressed air forced through perforations in tubes located at the bottom of the pond. A natural or photosynthetic stabilization pond relies on natural wave action and algae to provide oxygen needed by the bacteria.

ANAEROBIC WASTE TREATMENT

Anaerobic treatment processes have been used mostly for the digestion of concentrated sludges. However, they are receiving increased attention for use with some waste waters.

One such waste water treatment process is the anaerobic contact method, by which raw wastes high in BOD are mixed with recycled sludge solids and digested in a digestion chamber. The solids are then separated in a clarifier or other solids separation unit, and the remaining liquid is discharged as effluent. This is not a common method for treating typical domestic waste water.

A second method, the anaerobic filter process, as yet is too new for its potential for treating domestic waste water to be fully developed. In this method, waste water flows upward through a column filled with small rocks or other medium. Anaerobic bacteria grow and are retained on the medium and the treated effluent is discharged at the top of the column. This method appears well suited to treating waste waters low in BOD or other contaminants.

Anaerobic lagoons are used occasionally as a first stage in treating municipal waste water. These lagoons are heavily loaded with organic matter to maintain anaerobic conditions. The anaerobic bacteria are effective in stabilizing strong organic wastes. Facultative or aerobic lagoons are often used for further treatment.

Septic tanks are used principally for treating waste water from individual homes and, in rural areas, for sewage from schools, camps, trailers, parks, recreation facilities, and the like. Waste water is directed to tanks, often with two or more sections or chambers, where solids settle and are stabilized anaerobically. The effluent is then directed to leaching fields where it percolates into the ground. Removal of stabilized solids from septic tanks is normally required every 2 to 3 years.

CHEMICAL TREATMENT

Chemicals are sometimes used to help precipitate solids and improve the efficiency of biological treatment processes. In secondary treatment, chemicals are also used to control pH and to disinfect effluents before they are discharged. Treatment with chemicals is used extensively in tertiary treatment. In both secondary and tertiary treatment, processes using chemicals require physical units for mixing, precipitating, and settling.

4. TERTIARY TREATMENT

With stricter laws, rules, and regulations governing the discharge of pollutants to surface or ground water, many municipalities now must provide treatment beyond conventional secondary treatment. This advanced, or tertiary, treatment is often required to remove additional BOD, nutrients, and other contaminants that pollute receiving waters.

Many substances in municipal waste water are not greatly affected by conventional primary and secondary treatment. Such substances include calcium, potassium, sulfate, nitrate and phosphate ions, and many complex synthetic organic compounds. Their removal requires advanced treatment facilities. Physical, chemical, and biological unit operations are all applied in accomplishing the various objectives of tertiary treatment.

Some common constituents of waste water that may have to be removed by advanced treatment are:

Ammonia, which increases chlorine demand and may be toxic to fish.
Calcium (Ca) and magnesium (Mg), which increase water hardness.
Chlorides, which give salty taste and interfere with industrial processes.
Mercury (Hg), which is toxic to human beings and to aquatic life.
Nitrates (NO_3), which can cause methemoglobinemia in infants (blue babies) and stimulate eutrophication.
Phosphates (PO_4), which can stimulate eutrophication and interfere with some treatment processes.
Sulfates (SO_4), which have a cathartic action.

Removal of nitrogen and phosphorus to reduce eutrophication currently is receiving particular attention.

Advanced waste treatment processes are many and include air stripping of ammonia, filtration, distillation, flotation, reverse osmosis, carbon adsorption, chemical precipitation, ion exchange, nitrification, denitrification, and land application.

5. EFFLUENTS

The characteristics of typical raw domestic waste water and of effluent from secondary treatment plants are listed in chapter 4. Effluent characteristics vary widely, depending on such factors as nature of the area, treatment process, and even the time of year.

Primary treatment may remove 25 to 40 percent of the BOD_5 in incoming waste water. It removes a high percentage of settleable solids but does not remove 80 to 90 percent of the suspended solids as required by most regulations. Dissolved solids removal is minimal.

Secondary treatment normally removes 85 to 95 percent of the suspended solids and BOD_5 in raw waste water. Because more oxygen is available, more of the nitrogen will be in nitrate form in the effluent from trickling filters than in that from activated sludge plants. However, extended aeration added to the activated sludge process leads to greater nitrification and, consequently, more nitrate in the effluent.

Effluents from tertiary treatment plants vary in characteristics, depending on the primary objectives of the treatment plants. Removal of nitrogen or phosphorus to prevent overenrichment of receiving waters is a primary purpose of many tertiary treatment plants. Effluents with a low nutrient concentration can be expected from such plants.

6. SLUDGE TREATMENT AND DISPOSAL

Solids removed from the screening devices are sent through grinders or disintegrator pumps and returned to the waste water flow, disposed of in landfills, or incinerated. The screenings removed from waste water range in quantity from 0.5 to 30 ft^3 per million gallons, depending on size of the screening device and characteristics of the waste water.

Grit from the grit chambers is most commonly disposed of as fill. Covering may be required for the fill because some organic material is normally trapped in the grit chamber with the grit. Occasionally, the grit is incinerated. The grit separated from waste water ranges in quantity from about 0.3 to 24 ft^3 per million gallons of waste water treated, depending on the collection system and characteristics of the area served.

Sludge production per million gallons of waste water also varies widely. The yield of undigested sludge from primary settling basins is about 3,000 gallons (95 percent moisture). The activated sludge process yields about 20,000 gallons of sludge (98.5 percent moisture), and the trickling filter process about 750 gallons of sludge (92.5 percent moisture).

Because sludge from primary settling basins already has a relatively high solids content, it usually is not put through a thickening process. Sludge concentration can reduce the volume of activated sludge to be handled. Reducing the moisture content from 98.5 percent to 95 percent results in volume that is only 30 percent of the original. Mixtures of primary and activated sludge are occasionally thickened to a solids concentration of 5 or 6 percent.

Since raw sludge becomes offensive quickly, it is usually treated by anaerobic digestion, with digestion accomplished by micro-organisms in heated, covered tanks.

Raw sludge being anaerobically treated in a tank usually separates into four layers. First, digested sludge settles in a layer at the bottom of the tank. Sludge being actively digested then rests on the layer already digested. A supernatant liquor develops above the active sludge, and a layer of scum forms on top of the liquor. Methane gas, a product of anaerobic decomposition, is collected at the top of the tank and used to heat the new sludge being added. Methane gas is also occasionally used for other heating purposes.

Anaerobic sludge lagoons can be used in conjunction with small waste treatment plants if sufficient area for the lagoons is available. Two disadvantages, however, are that methane gas cannot be recovered from a lagoon or open pond and that digested sludge must be removed periodically to maintain lagoon capacity.

Aerobic sludge digestion is not as common as anaerobic digestion

but is used occasionally in small waste water treatment plants. It is sometimes used to stabilize activated sludge or mixtures of activated sludge or trickling filter sludge and primary sludge. Aerobic digestion is done in tanks similar to those for anaerobic digestion. Large quantities of air are forced through the mixture to maintain a dissolved oxygen (DO) content of 1 to 2 mg/l. Considerable energy is required for mixing and adding the required oxygen. Aerobic digestion, although higher in operational cost, produces a more stable and odorless end product that dewaters readily and is more easily disposed of than anaerobically digested sludge.

Sludge conditioning is an additional process used to improve dewatering. The two methods of conditioning most commonly used are chemical and heat treatment. The purpose of dewatering is to reduce the moisture content of sludge so that it can be handled as a semisolid for disposal. Methods of dewatering include spreading on drying beds, vacuum filtration, centrifugation, and pressure filtration. Incineration is used to reduce sludge to ash for easy disposal. Methods for disposal of sludge include spreading on soil; lagooning (a temporary expedient only); dumping of completely stabilized sludge, inert solids, or grit; sanitary landfilling by mixing with refuse; and ocean dumping, which is becoming more restricted.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 4. WASTE CHARACTERISTICS

Compiled by Charles E. Fogg, sanitary engineer, SCS, Washington, D.C.

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CHAPTER 4. WASTE CHARACTERISTICS

1. GENERAL

This chapter deals primarily with agricultural wastes and such other wastes that may be applied to the soil and its plant cover for treatment or disposal. Wastes become pollutants when they are introduced into air, water, or soil in excessive amounts or when they otherwise become offensive in the environment.

Excessive wastes in surface or ground water can deplete dissolved oxygen, increase the potential for excessive algal or plant growth, increase the risk of waterborne diseases, and add materials that can be toxic to man, animals, or plants. Pathogens along with other contaminants can be introduced by wastes into air. Offensive odors result. Excess wastes can render soil unproductive and offensive and add to the pollution of ground water and surface runoff. Each medium--air, water, soil--has a definite limit to the amount of various waste components it can safely assimilate.

2. WATER POLLUTION

A brief discussion of some of the more common constitutents of waste materials adversely affecting water follows.

BIOCHEMICAL OXYGEN DEMAND (BOD)

Biochemical oxygen demand of wastes depletes dissolved oxygen in the water of our streams and lakes. BOD is determined by incubating a mixture of waste and water under aerobic conditions for a specified time and measuring the oxygen used. An incubation period of 5 days is generally considered standard. The oxygen consumed is called BOD_5 (5-day BOD) of the waste.

Until recently, BOD_5 has been the principal measure of the pollution potential of domestic sewage. The degree of treatment achieved at sewage treatment plants is usually measured as a percentage reduction of BOD_5.

Occasionally a long-term BOD of waste is needed. Long-term BOD is determined by incubating the waste and water for an extended period such as 30 to 45 days. The resulting determination is BOD_{30} or BOD_{45}. For animal wastes and many food processing or manufacturing wastes, the long-term BOD, e.g., BOD_{30}, is usually many times greater than the BOD_5.

CHEMICAL OXYGEN DEMAND (COD)

Chemical oxygen demand is a measure of the oxygen required to reduce all oxidizable material in wastes. It is evaluated chemically by sulfuric acid and potassium dichromate to determine the quantity of oxygen required for total oxidation. COD often is only slightly greater than long-term BOD.

The effect of COD is to deplete the dissolved oxygen in water, just as BOD does. Wastes with high COD also cause additional deposits of sludge on the bottom of streams and lakes. These settled sludges exert a continuing benthal demand on dissolved oxygen in the waters above them.

The analytical procedure for determining COD is similar to that used by soil scientists for determining organic carbon (OC). COD can be converted to organic carbon by multiplying by 0.375 (assuming complete oxidation of the organic carbon). This value of organic carbon can be used to determine the carbon-nitrogen ratio of the waste.

CARBON-NITROGEN RATIO (C-N RATIO)

The carbon-nitrogen ratio governs the rate of waste decomposition in soil. Wastes with a C-N ratio greater than about 30 do not have enough nitrogen to maintain a microbial population adequate for active decomposition. These wastes decompose slowly and can withdraw nitrogen from the soil, thus causing nitrogen deficiency in plants. As decomposition proceeds, the C-N ratio decreases and the rate of decomposition increases.

Wastes with a C-N ratio less than 10 to 15 support large microbial populations and decompose readily. They rapidly release nitrogen to the soil as ammonia. Some of this ammonia converts to nitrate and is taken up by the plant, lost by denitrification, or leached through the soil. The nitrogen content of wastes applied to the land often limits the application to rates that prevent leaching of nitrates to ground water.

TOTAL SOLIDS (TS)

Total solids are the residue after water is evaporated from a waste sample and the remaining material is dried by heating to about 103° C. These solids in the liquid waste are suspended solids or dissolved solids. The suspended solids that settle to the bottom of a sample container are settleable solids. A determination of settleable solids is an indication of the amount of solids removable by sedimentation.

Raw domestic sewage usually contains less than 0.1 percent total solids; digested sludge from a waste treatment plant contains 3 to 7 percent. Liquid animal manure with a TS content of more than about 6 percent is difficult to pump through pipelines and spray nozzles.

Solids--floating matter, suspended solids, oil, and grease--in surface waters are unsightly and cause odor. Organic solids deplete dissolved oxygen and render wastes and receiving waters putrescible. Settleable solids form sludge banks. Pathogenic bacteria and other organisms make the waters dangerous to human and other life forms.

VOLATILE SOLIDS (VS)

Volatile solids are the solids driven off as gases when total solids are heated to 600° C for 1 hour. The solids remaining are known as fixed solids. As organic matter burns, the volatile portion is a measure of the amount of organic matter present in the waste. The ratio of volatile solids to total solids can vary between different wastes, but VS normally make up 60 to 85 percent of TS.

NITROGEN (N)

All animal and human wastes contain nitrogen. Ammonia nitrogen, often called free ammonia (NH_3), is the initial product from the decomposition of nitrogenous organic matter. When ammonia is oxidized, nitrites (NO_2) are formed. Nitrite forms of nitrogen are readily converted to nitrates (NO_3), the end product of oxidation of nitrogenous matter.

Nitrates are an important source of fertility in both soil and water. Since nitrates are highly stable and soluble in water, however, excessive amounts are readily leached through the soil to pollute ground water as well as surface water. Overenrichment of surface water thus promotes excessive algal and plant growth and causes generally undesirable conditions.

Water containing more than 45 parts per million (ppm) nitrate ion is unsafe for human consumption (see ch. 3: TERTIARY TREATMENT, nitrates). High nitrate content can also poison animals.

PHOSPHORUS (P)

Phosphorus is also a major constituent of animal and human wastes. Like nitrogen, it is a basic nutrient contributing to overenrichment of surface water. Unlike nitrogen, however, phosphorus in water does not leach through to ground water so readily because it is adsorbed on the clay particles of soil.

Water pollution by phosphorus is usually caused by direct runoff of water or wastes containing the nutrient to a stream or lake. Phosphorus also rides piggyback on eroded soil particles carried to streams and lakes.

POTASSIUM (K)

Potassium, also contained in animal and human wastes, is a nutrient necessary for plant growth. It is not usually a pollutant to surface or ground water and does not contribute to overenrichment of surface water. Because of its fertilizer value, knowledge of the K content of wastes applied to land is valuable.

DISSOLVED OXYGEN (DO)

Oxygen can be absorbed by water in small amounts. The amount of oxygen that can be absorbed, referred to as dissolved oxygen, depends on

water temperature and, to a lesser degree, on elevation and the amount of other substances in the water. Turbulent water absorbs oxygen more rapidly than still or slow-moving water. The amount of oxygen that pure water can absorb at mean sea level ranges from 14.6 mg/l at 0^{o} C (32^{o} F) to 7.6 mg/l at 30^{o} C (86^{o} F). Salt water at mean sea level containing 20,000 mg/l chloride becomes saturated with 11.3 mg/l oxygen at 0^{o} C and with 6.1 mg/l oxygen at 30^{o} C. Water at 5,000 and 10,000 feet above mean sea level can absorb 84 and 69 percent, respectively, of the oxygen it would absorb at mean sea level.

3. UNITS OF MEASURE

Production of wastes and components for various units of animals, food processed, etc., is commonly expressed in the United States as pounds per day (lb/day). Other units of measure can be determined by referring to appropriate conversion charts or factors.

The concentration of various components in wastes is commonly expressed as milligrams per liter or parts per million. One mg/l is 1 milligram (weight) in 1 million parts (volume), i.e., 1 liter. One ppm is 1 part by weight in 1 million parts by weight. Therefore, mg/l = ppm if a solution has a specific gravity equal to that of water.

Generally, substances in solution up to concentrations of about 7,000 mg/l do not materially change the specific gravity of the liquid, and mg/l and ppm are numerically interchangeable. Concentrations are sometimes expressed as mg/kg or mg/1,000 g, which are the same as ppm.

Occasionally, the concentration is expressed in percent. A 1 percent concentration equals 10,000 ppm. Very low concentrations are sometimes expressed as micrograms per liter (µg/l). A microgram is 1 millionth of a gram.

Some confusion exists in the chemical expressions for pollutants, especially for nitrogen and phosphorus. An example is the dually stated safe limit for nitrates in drinking water. Water containing 45 mg/l nitrate ion (NO_3) is considered unsafe. The same thing is said of water containing more than 10 mg/l nitrate nitrogen (NO_3-N). Both mean the same thing. The nitrate ion (NO_3) has a molecular weight of 62, whereas nitrogen (N) has a weight of 14. The NO_3 weight is just under 4.5 times the weight of N when expressed as a concentration.

Nitrogen concentration is sometimes expressed as N, NO_2, NO_3, NH_3, and so forth, but it is more commonly expressed as NO_2-N, NO_3-N, NH_4-N, organic N, etc. The same is true of phosphorus and its various forms: P, PO_4, and P_2O_5. Care must be taken to determine how concentrations are expressed when considering limiting the amounts that can be applied to the soil and its plant cover. Following are the atomic or molecular weights of nitrogen, phosphorus, potassium, and oxygen in their common forms:

Nitrogen	Phosphorus	Potassium	Oxygen
$N = 14$	$P = 31$	$K = 39$	$O = 16$
$NH_3 = 17$	$PO_4 = 95$	$K_2O = 94$	$O_2 = 32$
$NH_4 = 18$	$P_2O_5 = 142$		
$N_2 = 28$			
$NO_2 = 46$			
$NO_3 = 62$			

4. LIVESTOCK AND POULTRY MANURE

Estimates of manure production per head or per 1,000 lb live weight of livestock and poultry vary widely. The same is true of manure components. Variations are due to climate, types of feed, production methods, and measurement techniques. Onsite measurements and laboratory analyses of a given livestock operation are necessary to estimate accurately both manure production and quantities of components.

Sizes of domestic animals vary by species and breed. Mature beef cattle normally weigh 800 to 1,000 lb per animal; dairy cattle, 1,200 to 1,500 lb; horses, 1,000 lb or more; swine, 100 to 200 lb; laying hens and broilers, 4 to 5 lb; turkeys, 15 to 25 lb; and ducks, 4 to 6 lb.

Table 4-1 summarizes data on the daily production and composition of livestock manure from studies of fresh manure production by livestock and poultry across the country. The upper figure in each tabulation represents the average production per 1,000 lb live weight for fresh manure. Extremely high and low values have been excluded. The lower figure gives the general range of values. Comparable figures for people are also provided, assuming an average weight of 125 lb per person.

Actual production from livestock and poultry can be expected to vary from the values contained in table 4-1. For example, analyses of manure from laying hens studied at Cornell showed an average BOD_5 of only 1.6 lb/day per 1,000 lb live weight. Yet, usual BOD_5 production is about 3.4 lb/day. Beef cattle in Minnesota on a high-energy ration produced only 29 lb/day of manure per 1,000 lb live weight, compared to the more usual 62 lb/day reported.

Manure normally contains many other elements and compounds in addition to those listed in table 4-1. For example, analysis of swine manure from various parts of Michigan showed production of 0.5 lb calcium (Ca); 0.07 lb magnesium (Mg); 0.12 lb sulfur (S); 0.02 lb iron (Fe); 0.005 lb zinc (Zn); 0.004 lb boron (B); and 0.0014 lb copper (Cu) per 1,000 lb live weight per day.

Swine in Scotland consuming 328 mg/l Cu in feed produced 0.009 lb Cu per 1,000 lb live weight per day in manure. Copper inhibits biological treatment of wastes and must be considered when designing waste treatment facilities. Antibiotics commonly fed to livestock can appear in manure and are also thought to inhibit biological treatment and affect standard BOD_5 tests.

The foregoing points out the need, when planning an overall waste management system, for measuring and analyzing the manure produced

Table 4-1.--Daily production and composition of livestock manure (feces and urine)
[Upper figure is average; lower figures represent the range given in literature. Dashes indicate data not available or entry not appropriate]

	Dairy cattle	Beef cattle	Feeder swine	Breeder swine	Poultry	Ducks[1]	Sheep	Horses	Catfish	People
	lb/day/1,000 lb live weight									
Manure......................	85	62	69	50	53	---	36	50	---	31.2
	72-90	41-88	50-90		32-67		30-40	40-60		
Total solids................	9.3	8.9	7.2	4.3	13.9	[2]24	9.5	17.5	3.1	3.4
	6.8-13.5	6.0-11.1	6.0-9.0		9.0-17.4	[2]13-31	8.4-10.7		2.8-3.5	2.4-4.4
Volatile solids.............	6.9	6.9	5.7	3.2	10.8	[2]14.5	8.0	---	---	2.0
	5.7-7.9	4.8-8.2	4.0-7.0		8.0-12.9	[2]8.7-17.5	6.0-9.1			1.1-2.6
BOD_5........................	1.4	1.5	2.3	1.3	3.4	5.1	0.8	1.4	2.3	1.36
	0.8-1.8	1.0-1.8	2.0-2.8		1.6-5.5	4.1-7.6	0.7-0.9		1.1-4.9	0.6-2.10
COD.........................	8.4	7.9	5.9	5.2	12.5	---	10.0	---	---	3.12
	4.2-13.3	6.6-9.0	4.7-7.1		9.5-15.8		7.5-12.0			1.0-3.5
Total nitrogen as N.........	0.37	0.43	0.45	---	0.86	1.42	0.40	0.30	1.6	0.20
	0.29-0.51	0.30-0.58	0.20-0.70		0.45-1.50	1.17-1.62	0.34-0.45		0.7-2.5	0.14-0.26
Total phosphorus as P.......	0.069	0.090	0.17	---	0.40	0.62	0.075	0.12	0.25	0.024
	0.026-0.100	0.023-0.170	0.09-0.27		0.20-0.75	0.4-0.9	0.040-0.120		0.24-0.26	
Total potassium as K........	0.20	0.23	0.25	---	0.35	0.9	0.32	0.25	1.5	0.064
	0.08-0.35	0.11-0.38	0.10-0.60		0.12-0.50	0.6-1.2	0.24-0.40		0.7-2.4	

[1] Based on production figures per 1,000 ducks and assuming an average weight of 4 pounds per duck on swim water.

[2] Suspended solids.

under existing field conditions. Local data and experience provide the best basis for designing system components.

5. FEEDLOT AND BARNYARD RUNOFF

Variations in composition of runoff from feedlots and barnyards across the country are attributed to climate, slope, type of feed, nature of feedlot surface, and stocking rate. Winter runoff in northern climates contains much higher concentrations of waste components than summer runoff. Runoff in warm, dry areas, however, has higher concentrations of chemicals than that in cool, humid areas. A high concentration of salts can adversely affect vegetation of areas on which the runoff is applied.

Runoff from feedlots on flat slopes has higher concentrations of dissolved solids, K, Na, and chloride than that from similar feedlots on steeper slopes. Runoff from steep slopes has higher concentrations of total solids, P, and N and a higher chemical oxygen demand.

As one might expect, paved lots retain less initial rainfall and have a higher percentage of runoff than unpaved lots. Lots with a high concentration of livestock and manure retain more initial rainfall than those with a lower concentration. Because animals on high-energy feed produce less manure than those on high-roughage feed, a higher percentage of runoff can be expected from feedlots containing livestock on high-energy feed.

The manure pack on beef feedlots retains from 0.25 to 0.9 inch, averaging about 0.5 inch, of initial rainfall before runoff occurs. Available data show the runoff ranges from about 30 percent to over 60 percent of summer rainfall. Less runoff occurs on flatter slopes and high density stocking rate areas than on steeper slopes and low density stocking rate areas.

Table 4-2 presents data on feedlot runoff for two locations in Texas and one each in Kansas and Nebraska. Note the wide range in concentration of the various components.

There are not enough data on the characteristics of feedlot runoff in eastern United States to compare them with those for the Midwest and Southwest. This lack of information emphasizes the need for onsite measurements and analyses to properly design waste management systems for feedlot runoff.

6. FEEDLOT SOLID WASTES

The volume and characteristics of solid wastes removed from feedlots vary with climate, animal density, cleaning periods, and other factors.

A Mead, Nebr., study found that total dry matter removed was 0.9 and 2.34 tons per acre of feedlot for each day that cattle were in the feedlots at animal densities of 200 and 100ft^2 per head. This represents 17 to 21 lb dry matter per day per head. About 38 percent of the dry matter was volatile. Nitrogen and phosphorus removed averaged 27.3

Table 4-2.--Characteristics of feedlot runoff[1/]
[Upper figure is average; lower figures represent the range. Dashes indicate data not available]

	Austin Co., Texas	Bushland, Texas	Kansas	Nebraska
	mg/l	mg/l	mg/l	mg/l
Total solids	9,000	---	8,450	---
	2,080-42,500	5,000-50,000	214-19,250	2,400-17,400
Volatile solids..	4,500	---	3,890	---
	800-14,000	---	36-9,550	1,200-7,300
Nitrogen as N ...	50	---	675	---
	4-125	600-2,400	165-1,580	39-455
Phosphorus as P..	85	---	79	---
	5-305	100-500	9-242	14-47
Potassium as K ..	340	---	---	---
	20-740	900-2,100	---	---
Sodium	230	---	---	---
	65-700	400-1,100	---	---
Chloride	410	---	---	---
	30-890	1,250-2,200	---	---
COD	4,000	---	7,600	---
	500-14,000	---	800-16,000	1,300-8,250
Conductance	---	---	---	---
	---	[2/]6-10	---	---

[1/]Information for this tabulation was obtained from the unpublished paper "Water quality of storm runoff from a Texas beef feedlot" by D. L. Reddell and G. G. Wise, Texas A&M, Belleville, Tex. 1973.
[2/]Conductance is reported in millimhos per centimeter (mmho/cm).

and 2.5 lb per ton of dry matter, respectively. The electrical conductivity of the saturation extract averaged about 1.2 mmhos/cm (about 770 ppm dissolved salts) and pH ranged from 4.6 to 9.4.

Table 4-3 presents moisture COD, N, P, TS, VS, pH, and conductivity values for the period November 1968 to November 1970. The remaining values are for the period November 1969 to November 1970. The periods between cleaning of the lots ranged from 112 to 203 days.

In the southern High Plains region of northwest Texas, it was found that solid waste accumulation was affected most by ration composition. An all-concentrate finishing ration resulted in 2.3 lb dry waste accumulation per head per day while a 12 percent roughage ration resulted in an accumulation of 5.0 lb per head per day. In this study, cattle were concentrated on concrete-surface feedlots. The data in table 4-4 are based on studies of 13 to 27 head on concrete-surface feedlots for 136 to 173 days.

Table 4-3.--Characteristics of wastes removed from unpaved outdoor beef cattle feedlots[1/]

Characteristic	Animal density: 100 ft²/head	Animal density: 200 ft²/head
pH[2/]	4.6-9.2	5.1-9.4
Electrical conductivity[2/]..mmho/cm	0.4-1.6	0.6-1.6
Moisture content[2/] pct wet weight	33-59	33-63
Total solids[2/] pct wet weight	41-67	37-67
Volatile solids[2/] pct wet weight	8-25	11-24
Total N[2/] mg/l	1,500-8,600	1,100-10,000
Total P[2/] mg/l	59-1,200	59-1,200
COD[2/] mg/l	10,900-190,000	12,400-286,000
Sodium[3/] mg/l	410-1,246	475-1,010
Potassium[3/] as K mg/l	400-4,632	1,178-7,640
Calcium[3/] mg/l	532-3,574	224-3,346
Magnesium[3/] mg/l	236-1,880	633-2,356
Zinc[3/] mg/l	1.9-37.4	3.8-46.4
Copper[3/] mg/l	1.1-8.5	1.1-8.4
Iron[3/] mg/l	146-3,985	686-7,425
Manganese[3/] mg/l	18-1,224	39-245

[1/]Data summarized from Gilbertson, C. B., T. M. McCalla, J. R. Ellis, and W. R. Woods. Characteristics of manure accumulations removed from outdoor, unpaved beef cattle feedlots. Proc. Int. Symp. on Livest. Wastes, Columbus, Ohio April 19-22, 1971.

[2/]From November 1968 to November 1970.

[3/]From November 1969 to November 1970.

Table 4-4.--Solid waste accumulation on concrete-surface feedlots[1/]

	Animal density	Average weight for period	Waste produced per day	Dry matter produced per day
	ft²/head	lb/head	lb/head	lb/head
Cattle fed 173 days:				
All-concentrate ration (open lot)	95	745	4.8	2.3
12 percent roughage (open lot)	88	775	10.7	5.0
Cattle fed 136 days:				
10 percent roughage (covered lot)	42	678	8.3	4.0
10 percent roughage (open lot)	41	679	9.2	4.5
10 percent roughage (continuously wet lot)	84	649	10.9	4.8

[1/]From Wells, D. M., G. F. Meenaghan, R. C. Albin, and others. Characteristics of wastes from Southwest beef cattle feedlots. Proc. 1972 Cornell Agr. Waste Manage. Conf., Syracuse, N.Y.

7. MANURE LAGOON INFLUENT AND EFFLUENT

Influent wastes to lagoons generally contain the components of the excreted manure diluted by wash water and other added water. Table 4-5 shows the normal range in concentration of manure components when manure influent is diluted to a total solids content of 4 percent.

It should be noted that aerobic lagoon influent of wastes and water generally is less than 1 percent total solids but may range from less than 1 percent to more than 10 percent. This wide range emphasizes the need for analyses of samples taken at the site.

The composition of the effluent from lagoons depends on influent characteristics, period of retention, rainfall and evaporation, seepage losses, and climate. Data at this time are insufficient for a table showing composition of typical lagoon effluents.

Evidence indicates that properly functioning anaerobic lagoons can remove 75 to 80 percent of total solids, 85 to 90 percent of COD, 60 to 70 percent of BOD_5, and 45 to 50 percent of nitrogen. A substantial amount of phosphorus remains with the sludge in the lagoon. Reliable figures on the percentage of influent potassium remaining with the sludge are not available.

Table 4-5.--Composition of manure lagoon influent (diluted to 4 percent total solids content)
[Upper figure is typical; lower figures are the range]

Component	From dairy cattle	From beef cattle	From swine	From poultry
	mg/l	mg/l	mg/l	mg/l
Total solids..	40,000	40,000	40,000	40,000
Volatile solids.	29,700 25,000-34,000	31,000 21,000-37,000	31,600 22,000-39,000	31,100 23,000-37,000
BOD_5..........	6,000 3,400-7,700	6,700 4,000-8,100	12,800 11,000-16,000	9,800 4,600-16,00
COD..........	36,200 18,000-57,000	35,600 30,000-40,000	32,800 26,000-39,000	36,000 27,000-46,000
Nitrogen as N .	1,600 1,250-2,200	1,900 1,300-2,600	2,500 1,100-3,900	2,900 1,300-4,300
Phosphorus as P.	300 110-430	400 100-760	950 500-1,500	1,100 580-2,200
Potassium as K.	860 340-1,500	1,100 500-1,700	1,400 600-3,300	1,100 340-1,400

Properly operated aerobic manure lagoons with sufficient retention time can be expected to remove up to 80 or 90 percent of the entering BOD_5 and 80 or 90 percent of the volatile solids. Nitrogen removal ranges from 15 to 40 percent. The effluent from aerobic lagoons contains algae, which as they die exert BOD on receiving waters.

The effluent from both anaerobic and aerobic manure lagoons normally contains too much BOD_5 and other waste components for discharge to surface waters.

8. MUNICIPAL SEWAGE

The composition of raw municipal sewage depends on the area served. Amount and types of industry, water use per capita, whether garbage grinders are used, and nonresidential connections such as hospitals and laundries all influence the composition of sewage. Table 4-6 shows typical concentration of the common components of raw domestic sewage.

Table 4-6.--Composition of typical raw domestic sewage

Component	Concentration
	mg/1
BOD_5	200
COD	450
Total solids	500
Volatile solids	350
Suspended solids	300
Volatile suspended solids	250
Dissolved solids	200
Volatile dissolved solids	100
Nitrogen as N	30
Phosphorus as P	10
Potassium as K	10
Total salts	200
Boron	0.2
Sodium	50
Magnesium	5
Calcium	10
Sulfate	20
Chloride	100
Alkalinity as $CaCO_3$	125

9. EFFLUENT AND SLUDGE FROM MUNICIPAL SEWAGE TREATMENT PLANTS

The characteristics of effluent and sludge from sewage treatment plants depend on characteristics of the raw waste entering the plant and type and efficiency of the treatment provided.

Table 4-7 shows the characteristics of secondary effluent to be expected from typical municipal plants. Considerable variation can

Table 4-7.--Composition of effluent from typical secondary waste treatment plants
[Dashes indicate data not available]

Component	Concentration: Typical	Concentration: Range
	mg/l	mg/l
pH	1/ 7.0	1/ 6.5-8.0
BOD_5	20	15-30
COD	50	25-70
Total solids	500	350-950
Suspended solids	25	15-40
Dissolved solids	475	300-900
Nitrogen as N	20	15-35
Phosphorus as P	10	7-15
Potassium as K	12	10-14
Chloride	100	30-200
Iron	0.5	0.1-5.5
Copper	0.13	0-1.4
Cadmium	0.1	0-0.2
Nickel	0.2	0.03-0.35
Zinc	0.2	0.1-0.5
Lead	0.05	0.01-0.1
Boron	0.2	0-1.0
Calcium	40	25-60
Magnesium	17	15-25
Manganese	0.2	---
Sodium	40	35-100
Aluminum	0.9	---
Chromium	0.2	---

1/ pH is reported in units.

be anticipated from one plant to another and from one time of year to another.

Sludge from secondary treatment plants is normally about 3 to 7 percent solids. Components of the sludge are in much greater concentration than those in the effluent, which is generally less than 0.1 percent solids.

Table 4-8 is based on an analysis of activated sludge from a plant in Chicago, Ill.

Table 4-8.--Composition of sludge from a secondary waste treatment plant[1]

Component	Range in concentration
	mg/l
Total solids..............	27,500-34,300
Mineral.................	13,200-17,800
Organic	14,300-16,500
Alkalinity as $CaCO_3$.......	2,460-2,750
Aluminum..................	227-636
Arsenic...................	(2/)
Boron.....................	0.9-5.1
Cadmium...................	1.0-2.4
Calcium...................	1,180-1,240
Chloride..................	170-490
Chromium..................	26-49
Cobalt....................	(2/)
Copper....................	24-32
Iron......................	1,500-1,666
Potassium as K............	114-152
Magnesium.................	291-446
Manganese.................	14-143
Total nitrogen as N.......	1,450-1,767
Ammonia as N..............	528-790
Sodium....................	119-129
Nickel....................	Trace-3
Phosphorus as P...........	680-740
Lead......................	6-90
Silicon...................	2,773-9,800
Sulfur....................	45-288
Zinc......................	90-92

1/Activated sludge from a waste-water treatment plant at Chicago, Ill.

2/Not detected.

10. FRUIT AND VEGETABLE PROCESSING WASTES

There is no effluent from fruit and vegetable processing plants that can be called typical. BOD and suspended solids are usually high (300 to 5,000 mg/l) after raw waste water has been screened and allowed to settle. Nitrogen and phosphorus concentrations are usually low (10 to 100 mg/l and 3 to 30 mg/l, respectively). These wastes often have a high sodium and chloride content.

Table 4-9 lists the concentration of waste components from various kinds of processing plants. The composition in the table is not necessarily typical; rather, it illustrates the variability found. Values above and below those listed are also occasionally reported.

Table 4-9.--Composition of vegetable, fruit, and cereal wastes from various processing plants
[Dashes indicate data not available]

Component	Vegetables, canned			Potatoes		Sweetpotatoes					
	General	Tomatoes	Corn	Steam peeled	As french fries, etc.	Steam peeled	Lye peeled	Sugar beets	Citrus	Wine	Beer
	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1
pH	1/5.6-7.2	1/4.8	1/6.6	1/6.4	1/7.3-12.0	1/5.8	1/10.3	1/7.1	1/6.3-8.4	1/7.4-7.9	1/3-14
Electrical conductivity	2/0.2-2.8	2/1.3	2/0.7	2/0.7	---	2/0.4	2/9.5	2/0.3	---	---	---
Total solids	400-2,500	5,000	5,250	1,900	300-3,000	3,100	30,000	3,200	---	---	---
Volatile solids	250-1,500	4,000	3,900	1,700	---	2,800	20,000	1,500	---	---	---
Suspended solids	100-1,500	750	950	1,200	---	1,300	7,000	1,000	200-700	150	200-2,700
Dissolved solids	300-2,000	4,250	4,300	1,700	---	1,800	23,000	2,200	---	---	---
BOD_5	200-2,000	---	---	---	1,000-5,000	---	10,000	930	1,000-2,000	1,010	1,000-8,000
COD	300-4,000	5,500	7,000	1,160	2,000-10,000	3,800	27,000	1,610	1,500-3,000	---	---
Nitrogen as N	10-50	---	---	---	100	---	200	16	3-20	---	---
Phosphorus as P	2-23	5	16	5	17	6	35	3.4	1-5	---	---
Potassium as K	7-35	60	60	60	---	43	379	88	---	---	---
Sodium	20-350	120	75	120	---	51	3,750	222	---	---	---
Calcium	10-40	80	18	80	---	16	60	178	---	---	---
Magnesium	8-15	16	18	16	---	15	40	66	---	---	---
Chloride	80-1,000	40	28	175	---	28	340	400	---	---	---
Alkalinity as $CaCO_3$	10-150	---	---	---	---	---	---	540	---	---	---

1/ pH is reported in units.

2/ Electrical conductivity is reported in millimhos per centimeter.

11. MEAT PROCESSING WASTES

Types of plant processes and the extent of byproduct recovery are major influences on the composition of effluents from slaughterhouses and packinghouses processing meat. Blood recovery, now common, greatly reduces the pollution load in effluents. Pure blood has a BOD_5 of over 150,000 mg/l and a COD of nearly 220,000 mg/l. The blood from each 1,000 lb of animal killed contains about 4.7 lb BOD_5 and 6.5 lb COD. Paunch content (rumen), also commonly recovered, has a BOD_5 of about 50,000 mg/l and COD of about 177,000 mg/l. The paunch content of each 1,000 lb of animal killed has about 2.5 lb BOD_5 and 8.8 lb COD. Grease recovery also reduces waste concentration in effluents.

Table 4-10 shows what can be expected in effluents from meat processing plants. These figures represent the concentration of components of effluents from which blood and rumen have been excluded.

12. DAIRY PROCESSING WASTES

The volume and strength of milkhouse wastes depend on the care and management practiced in the milkhouse and in cleaning procedures. For example, deposited manure flushed during cleanup adds substantially to the concentration of pollutants in milkhouse effluent. With good milkhouse management, about 0.08 to 0.15 lb BOD_5 per day is contributed per cow.

Table 4-10.--Composition of slaughterhouse and packinghouse wastes
[Dashes indicate data not available]

Component	Poultry	Hogs and beef
	mg/l	mg/l
pH	1/7.1	1/7.0
Electrical conductivity	2/0.5	---
Alkalinity as $CaCO_3$	---	400
Total solids	800	2,600-5,800
Volatile solids	700	2,000-3,000
Suspended solids	500	1,000-1,500
Dissolved solids	300	1,100-4,300
BOD_5	500	1,400-2,600
COD	800	3,100-4,400
Nitrogen as N	---	140-150
Phosphorus as P	4	---
Potassium as K	23	---
Sodium	37	---
Calcium	32	---
Magnesium	8	---
Chloride	300	---
Grease	300	500-550

1/pH is reported in units.
2/Electrical conductivity is reported in millimhos per centimeter.

Table 4-11 shows the range and average concentration of components of milking center wastes. The figures for average concentration reflect good milking center management.

Table 4-12 gives BOD_5 data for dairy food processing plants obtained by a survey of 57 plants.

Table 4-11.--Composition of milking center wastes
[Dashes indicate data not available]

Component	Range	Average
	mg/l	mg/l
pH................	1/6.5-7.4	1/7.0
Total solids.......	800-10,400	5,000
Volatile solids....	---	---
Suspended solids...	200-7,800	2,700
Dissolved solids...	---	2,300
BOD_5..............	600-2,500	1,500
Nitrogen as N......	60-740	250
Phosphorus as P....	50-540	200

1/ pH is reported in units.

Table 4-12.--BOD_5 of waste water from dairy food plants[1/]

Product	BOD^5 per 1,000 lb milk processed	BOD_5 concentration in effluent
	lb	mg/l
Milk.................................	4.20	1,290
Cheese...............................	2.04	650
Ice cream............................	5.76	2,060
Condensed milk.......................	7.60	3,620
Butter...............................	0.85	1,060
Powdered milk........................	2.27	610
Cottage cheese	34.00	5,670
Cottage cheese and milk..............	3.47	1,890
Ice cream, cottage cheese, and milk...	6.37	2,530
Mixed products.......................	3.09	1,320
Overall..............................	5.85	2,400

1/ From data presented by W. J. Harper and J. L. Blaisdell of Ohio State University at the Second National Symposium on Food Processing Wastes, 1971.

The ratio of BOD_5 to COD in raw dairy-plant wastes ranges from 0.10 to 0.88 and averages 0.53. Detergents or matter other than milk in the waste water may slow biological oxidation and yield BOD_5 tests indicating ratios of 0.4 or less.

Table 4-13 shows the range and average concentration of various components of waste water from dairy food plants.

Note that, except for nitrogen, raw whey has a high concentration of pollutants. Studies suggest the following values as representative of raw whey strength (pH 4.3).

	mg/l
Total solids	63,000
Volatile solids	57,000
BOD_5	35,000
COD	70,000
Nitrogen as N	15
Phosphorus as P	530
Calcium	510
Chloride	1,950

Table 4-13.--Composition of waste water from dairy food plants
[Dashes indicate data not available or entry not appropriate]

Component	Concentration Range	Concentration Average
	mg/l	mg/l
pH	[1]5.3-9.4	[1]7.1
Total solids	135-8,500	2,400
Volatile solids	57-4,700	1,500
Suspended solids	24-5,700	---
BOD_5	15-4,800	2,100
Nitrogen as N	15-180	76
Phosphorus as P	11-160	50
Potassium as K	11-160	67
Sodium	60-807	322
Calcium	57-112	37
Magnesium	25-49	---
Chloride	48-469	276

[1]pH is reported in units.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 5. THE ROLE OF SOILS IN WASTE MANAGEMENT

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Contents

CHAPTER 5. THE ROLE OF SOILS IN WASTE MANAGEMENT

1. GENERAL

Soil, as the word is used in this text, is a collection of natural bodies on the earth's surface, in places modified or even made by man of earthy materials, containing living matter and supporting or capable of supporting plants outdoors. The upper limit of soil is air or shallow water. At its margins soil grades to deep water or to barren areas of rock or ice. Plant roots commonly colonize the upper soil horizons. Chapter 6 describes soil-water-plant relationships as well as nutrient uptake by plants.

Soils are used as absorption fields for septic systems and as disposal sites for biodegradable material applied to the land. Excavations in soils are used for sanitary landfills, sewage lagoons, and temporary storage basins for liquid waste. Completely effective filter systems would destroy BOD, utilize biostimulants such as phosphates and nitrates or remove them by some nonpolluting mechanism, provide long-term storage for harmful trace elements such as heavy metals, and deactivate virus or other pathogenic organisms and pesticides. Chapter 14 discusses pesticides and trace elements.

Effective filter systems are those permeable enough to allow percolation of purified water through and from the system but in which the percolation rate is slow enough to allow reduction of BOD and utilization of biostimulants such as phosphates and nitrates.

Completely effective sites for sanitary landfills, sewage lagoons, and temporary storage basins would be impervious and prevent the movement of any leachate. Chapters 9, 10, 12, and 13 discuss lagoons and sanitary landfills.

SOIL-WASTE INTERACTIONS

Filtration

In soil-waste systems, liquid wastes percolate through the soil and the particles in suspension are trapped at the surface or in the pore spaces. The particulate content of liquid wastes usually is nonsoluble organic material. Substances in solution such as soluble salts or sugar are not removed.

BOD and Soils

Organic substances in suspension and solution enter soils as part of the applied waste. Aerobic soil organisms use the organic wastes as food. Oxygen from the soil atmosphere is used in this oxidation process, and BOD of the waste is reduced. Some of the end products are resistant to breakdown and remain for years as part of the soil organic matter.

Chemical Precipitation

Some waste constituents in solution in the soil water are removed from solution by chemical precipitation. The precipitates that are relatively insoluble can be held in the soil for a long time. For example, phosphorus is precipitated and immobilized in soils with available calcium, iron, or aluminum. Heavy metals are precipitated in soils in which pH is near 7; if the soil pH drops, the heavy metals revert to soluble forms.

Adsorption

Other waste constituents in solution and colloidal waste particles are held on the surface of soil particles by adsorption. The adsorbed cations (positive charge) can be returned to the soil solution through exchange processes. Particles in the colloidal size range, such as those of clay or organic matter, and microbes, commonly have a negative surface charge. The surface charge causes the particles to function as small magnets and attract particles with a positive charge.

2. PROPERTIES USED IN SOIL RATING GUIDES

AVAILABLE WATER CAPACITY

Available water capacity is a measure of the soil water that is available to plants. An estimate of available water capacity is the water retention difference (water held at 15-bar tension minus that held at 1/3- or 1/10-bar tension). Plants extract more water from the top part of the soil than from the deeper parts. This property is used to rate soils as sites for disposal of biodegradable material applied to the upper horizons. Estimates of water retention difference or available water capacity are available for many soils in soil survey investigation reports, in published soil surveys, and in computer storage.

CONSISTENCE

Soil consistence comprises the attributes of soil material that are expressed by degree and kind of cohesion and adhesion or by resistance to deformation or rupture. Soil consistence is dependent on the soil water state (dry, moist, or wet). Moist soil consistence is a property used to rate soil suitability as a source of cover material for sanitary landfills. Moist soil consistence is reported as loose, very friable, friable, firm, very firm, and extremely firm. Consistence is determined by pressing a soil ped between the thumb and forefinger. Consistence values are included in all soil series descriptions.

DEPTH TO BEDROCK

Depth to bedrock is used to rate soil suitability for septic tank absorption fields, trench-type sanitary landfills, and sewage lagoons. For sanitary landfills a distinction is made between hard (nonrippable) and rippable bedrock.

DEPTH TO WATER TABLE

Minimum annual depth to phreatic water is used to rate soil suitability for septic tank absorption fields, sewage lagoons, and sanitary landfills, whether trench or area type. Prevention of water-table pollution is the important consideration.

FLOODING

Flooding is used to rate soil suitability for septic tank absorption fields, sewage lagoons, sanitary landfills whether trench or area type, and sites for disposal of biodegradable material applied to the upper horizons. In this context ponding is considered to be flooding. Flooding is a function of soil position and of stream control installations.

INFILTRATION RATE

The infiltration rate is the rate at which water enters the soil surface horizon. It is used to evaluate soil for disposal of liquid carrying biodegradable material applied to the upper horizons. Infiltration is influenced by surface sealing tendency, slope and configuration, surface texture, frozen vs. nonfrozen surfaces, and kind and growth stage of vegetation.

ORGANIC MATTER

Soil organic matter is composed primarily of material resistant to alteration, such a lignin and humic acid. The organic matter content of the subsoil is commonly lower than that of the surface horizon. Organic matter content is used to rate soil for sewage lagoons, which are commonly constructed in the subsoil. Subsoil horizon properties, therefore, are the values used in rating soils. Organic matter content of many soils is reported in soil survey investigation reports and in published soil surveys.

PERCOLATION

Percolation is the movement of liquid through a porous medium. The percolation rate is determined by measuring the rate of water removal from a straight-sided hole bored or dug into the soil. Commonly, the soil surrounding the hole is saturated before the rate of water removal is measured. The percolation rate is measured at individual sites. It is usually more rapid than the permeability rate.

PERMEABILITY

Permeability is estimated on the basis of soil characteristics observed in the field that influence the downward movement of water in the soil, particularly soil structure, porosity, and texture. The permeability rate is expressed in inches per hour (in/hr) as very slow (<0.06), slow (0.06-0.20), moderately slow (0.20-0.6), moderate (0.6-2.0), moderately rapid (2.0-6.0), rapid (6.0-20), and very rapid (> 20). Permeability is used to evaluate soils for septic tank absorption fields, sewage lagoons, sanitary landfills whether trench or area type, and sites for disposal of biodegradable material applied to the upper horizons. The permeability rate of the most slowly permeable layer of soil beneath the surface horizon is the one reported in a soil series description.

RUNOFF

Runoff is expressed as the rate of water movement from a site by flow over the soil surface. It is used to evaluate soil suitability for use as sites for disposal of biodegradable material applied to the surface horizon. Runoff is influenced by slope and surface configuration, frozen vs. nonfrozen surface, infiltration rate, permeability rate, soil water content, storm intensity and duration, soil structure, and cropping patterns.

SLOPE

Soil slope is a property of surface configuration and deviation from a horizontal plane. Soil slope is used to rate soil suitability for septic tank absorption fields, sewage lagoons, sanitary landfills whether trench or area type, and sanitary landfill cover material.

SOIL DRAINAGE CLASS

Soils are grouped according to the rate of water removal in relation to the water supply. Soil drainage classes are:

1. Very poorly drained. Water remains at or on the surface during most of the growing season.
2. Poorly drained. The soil is saturated or remains wet for long periods during the growing season.
3. Somewhat poorly drained. Where not artificially drained, the soil remains wet enough of the time to limit crop selection and growth.
4. Moderately well drained. The soil is wet for a small part of the growing season but long enough periodically to affect some crops.
5. Well drained. Water is removed from the soil readily but not rapidly.
6. Somewhat excessively drained. Water is removed from the soil rapidly in relation to supply.

7. Excessively drained. Water is removed from the soil very rapidly in relation to supply.

This property is used to rate soil suitability for sanitary landfills whether trench or area type, sanitary landfill cover material, and sites for disposal of biodegradable materials applied to the upper horizons. Many somewhat poorly drained and wetter soils can be tiled or ditched if an outlet is available. Some of them can be diked and pumped if no gravity outlet exists. These corrective measures can create the aerobic zone needed for waste disposal, but the effluent removed should be monitored for pollutants such as nitrates and, when necessary, treated to remove the pollutants.

STONINESS OR ROCKINESS

Stoniness refers to a content of stones larger than 10 inches in diameter. Rockiness refers to an area in which bedrock crops out or the soil over hard bedrock is too shallow for use. These properties are used to rate soil suitability for septic tank absorption fields, trench-type sanitary landfills, and cover material for area-type sanitary landfills.

TEXTURE[1/]

Texture refers to the proportions of the various size groups of individual grains (sand, silt, and clay) in a total mass. This property is used to rate soil suitability for sewage lagoons, trench-type sanitary landfills, and cover material for area-type sanitary landfills. Many systems of texture classification have been devised and used. Those used in soil guides issued by SCS include the USDA soil texture classification, the Unified soil classification, and the American Association of State Highway Officials (AASHO) soil classification.

3. EXAMPLES OF SOIL DESCRIPTIONS AND RATINGS

This section illustrates how the major soil in all areas delineated by a given mapping unit is rated. Since soils differ within the mapping unit, onsite evaluation at a proposed construction site is necessary for detailed planning.

The mapping unit Svea loam, 0 to 2 percent slopes, as defined for the soil survey of La Moure County, N. Dak., has been selected as an example.[2/] Ratings for soil waste systems following SCS guides are given. The soil description follows.

[1/] Texture in the USDA classification considers only material <2mm. The Unified and AASHO systems, included here for convenience, classify material >2mm as well as that <2mm.

[2/] Thompson, D. G. Soil survey of La Moure County and parts of James River Valley. 123 p. 121 pl. Soil Cons. Serv., U.S. Dep. Agr. 1971.

Svea loam, 0 to 2 percent slopes (Sv). This soil occurs on glacial till plains. Included in mapping were areas, less than 2 acres in size, of Barnes, Hamerly, and Tonka soils.

Most of the acreage is cultivated. Small grain, corn, flax, and alfalfa are suitable crops. Management practices are needed to conserve moisture and maintain fertility. Erosion is not a problem. Stubble-mulch tillage, management of crop residue, establishing windbreaks, and fertilizing are beneficial practices. Trees for field and farmstead windbreaks are well suited.

The Svea series consists of deep, nearly level, moderately well drained soils on glacial till plains in La Moure and Dickey Counties. These soils formed in medium textured to moderately fine textured glacial till.

In a typical profile the surface layer, about 10 inches thick, consists of black loam. The subsoil, about 11 inches thick, consists of very dark grayish brown, friable loam that has moderate medium prismatic structure breaking to moderate coarse subangular blocky. The underlying material consists of mottled, light olive brown, light clay loam and loam. This material is moderately calcareous to calcareous. It has an accumulation of segregated lime just below the subsoil.

Permeability is moderate in the subsoil and moderately slow in the substratum. The moisture-holding capacity is high. These soils are well supplied with organic matter.

Most areas of Svea soils are cultivated along with the closely associated Barnes soils. Small grain, corn, flax, and alfalfa are well suited.

The Svea soil is rated for each type of disposal system covered by SCS soil rating guides. The inclusions--soils in the Barnes, Hamerly, and Tonka series--in the Svea loam mapping unit could be rated by using the same procedures. The numbered guide sheets referred to for each item are in the SCS guide for interpreting engineering uses of soils.[3/]

SEPTIC TANK ABSORPTION FIELDS

A septic tank absorption field is a soil absorption system for sewage disposal. It is a subsurface tile system laid in such a way that effluent from the septic tank is distributed with reasonable uniformity into the natural soil. Criteria used for rating soils (slight, moderate, and severe) for use as absorption fields are based on the limitations of the soil to absorb effluent. Use guide sheet 3.

[3/] Soil Survey Staff. Guide for interpreting engineering uses of soils. 87 p. Soil Cons. Serv., U.S. Dep. Agr. 1971.

Using the format provided by this guide, Svea soils as in mapping unit Svea loam, 0 to 2 percent slopes, rate as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Permeability	Moderate in subsoil	Slight
Hydraulic conductivity..	Usually >1 in/hr	Slight
Percolation rate	Commonly greater than permeability.	Slight
Depth to water table....	Water table not mentioned, apparently is deep.	Slight
Flooding	None	Slight
Slope	0-2 percent	Slight
Depth to hard rock, bedrock, or other impervious material.	Soils on glacial till; bedrock not mentioned, apparently is deep.	Slight
Stoniness class	0	Slight
Rockiness class	0	Slight

The major part of the mapping unit has slight limitations for septic tank absorption fields. Inclusions of Tonka soil in the mapping unit have severe limitations for septic tank absorption fields because they are occasionally ponded.

SEWAGE LAGOONS

Types and functions of lagoons are discussed in chapters 9 and 12. The soils must be considered for two functions: (1) as a vessel for sewage impoundment (usually subsoil) and (2) as material for the embankment. Use guide sheet 4.

Svea soils as in the mapping unit Svea loam, 0 to 2 percent slopes, rate as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Depth to water table ...	Water table not mentioned, apparently is deep.	Slight
Permeability	Moderately slow in substratum.	Slight
Depth to bedrock	Mapping unit on glacial till; bedrock not mentioned, apparently is deep.	Slight
Slope	0-2 percent	Slight
Coarse fragments	<20 percent	Slight
Surface area covered with coarse fragments.	<3 percent	Slight
Organic matter	<2 percent below 21 inches	Slight
Flooding	None	Slight
Soil groups (Unified soil classification system).	CL	Slight

The major part of the mapping unit has slight limitations for sewage lagoons. Inclusions of Tonka soil in the mapping unit have severe limitations because they are occasionally ponded.

SANITARY LANDFILLS

Sanitary landfills are discussed in chapter 13. Soil information is useful for eliminating sites with severe limitations. Trench-type sanitary landfills commonly extend to a depth of 15 ft, whereas excavations for area-type landfills are shallow. Because of depth and digging equipment requirements, the guide for trench-type landfills has several more items affecting use than the guide for area-type landfills. Those sites rated as having only slight limitations according to soil information should be investigated further and to greater depth for information on properties other than those observed normally for soil characterization. (See chapter 7 for a discussion of geologic considerations.) Use guide sheets 7 and 8 to rate limitations of soils for use as trench-type and area-type sanitary landfills, respectively.

Trench-Type Sanitary Landfills

Svea soils as in the mapping unit Svea loam, 0 to 2 percent slopes, rate as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Depth to seasonal high water table.	Water table not mentioned, apparently is deep.	Slight
Soil drainage class ..	Moderately well drained	Slight
Flooding	None	Slight
Permeability	<2 in/hr	Slight
Slope	0-2 percent	Slight
Soil texture	Loam	Slight
Depth to bedrock	Soils on glacial till; bedrock not mentioned, apparently is deep.	Slight
Stoniness class	0	Slight
Rockiness class	0	Slight

The major part of the mapping unit has slight limitations for trench-type sanitary landfills. Inclusions of Tonka soils in the mapping unit have severe limitations because they are occasionally ponded.

Area-Type Sanitary Landfills

Svea soils as in the mapping unit Svea loam, 0 to 2 percent slopes, rate as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Depth to seasonal high water table.	Water table not mentioned, apparently is deep.	Slight
Soil drainage class ...	Moderately well drained	Slight
Flooding	None	Slight
Permeability	<2 in/hr	Slight
Slope	0-2 percent	Slight

The major part of the mapping unit has slight limitations for area-type sanitary landfills. Inclusions of Tonka soils in the mapping unit have severe limitations because they are occasionally ponded.

Sources of Cover Material for Area-Type Sanitary Landfills

Many area-type sanitary landfills require an auxiliary source of cover material. Use guide sheet 9 to rate the soils for this purpose. Ratings are in terms of suitability rather than limitations.

Svea soils as in the mapping unit Svea loam, 0 to 2 percent slopes, rate as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Moist consistence	Friable	Good
Texture	Loam to 21 inches	Good
Thickness of material..	<40 inches	Fair
Coarse fragments	<15 percent	Good
Stoniness class	0	Good
Slope	0-2 percent	Good
Drainage class	Moderately well drained	Good

The major part of the mapping unit has fair suitability for use as a source of cover material for sanitary landfill areas because of the thickness of suitable material. Inclusions of Tonka soil in the mapping unit have fair suitability because of dominant texture and common wet consistence.

DISPOSAL OF BIODEGRADABLE MATERIAL BY LAND APPLICATION

Land application methods are discussed in chapter 11. SCS has issued an interim guide for rating limitations of soils for disposal of waste.4/

4/Soil Survey Staff. Interim guide for rating limitations of soils for disposal of waste. 26 p. (Mimeographed) Soil Cons. Serv., U.S. Dep. Agr. 1973.

Application of Liquid Wastes

Using the format provided by table 1 in the interim guide, Svea soils as in the mapping unit, Svea loam, 0 to 2 percent slopes, rate for land application of liquid wastes as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Permeability	Moderately slow	Moderate
Infiltration rate ...	Moderate	Slight
Soil drainage class..	Moderately well drained	Slight
Runoff	Very slow or slow	Slight
Flooding	None	Slight
Available water capacity to 60 inches or to a limiting layer.	High	Slight

The major part of the mapping unit has moderate limitations for land application of liquid wastes because of its moderately slow permeability. Inclusions of Tonka soils in the mapping unit have severe limitations because they are occasionally ponded.

Application of Solid Wastes

Using the format provided by table 2 in the interim guide, Svea soils as in the mapping unit, Svea loam, 0 to 2 percent slopes, rate for land application of solid wastes as follows:

Item affecting use	Character (degree) in Svea soils	Rating
Permeability	Moderately slow	Moderate
Soil drainage class ...	Moderately well drained	Slight
Runoff	Very slow or slow	Slight
Flooding	None	Slight
Available water capacity to 60 inches or to a limiting layer.	High	Slight

The major part of the mapping unit has moderate limitations for land application of solid wastes because of its moderately slow permeability. Inclusions of Tonka soils in the mapping unit have severe limitations because they are occasionally ponded.

CHAPTER 6. THE ROLE OF PLANTS IN WASTE MANAGEMENT

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CHAPTER 6. THE ROLE OF PLANTS IN WASTE MANAGEMENT

1. SOIL-WATER-PLANT RELATIONSHIPS

Plants are well equipped to neutralize wastes. In the process of translocation, dissolved food and organic compounds in the plant move through it (downward) via conductive plant tissue called phloem, and water and minerals that are taken in move through it (upward) via tissue called xylem. In standard crop production, translocation is an accepted and ordinary plant function. In neutralizing or recycling wastes on land, however, it merits special attention because, for this use, the amount of additional water a growing plant can take up and the additional amounts and kinds of minerals it can use are basic considerations.

In ranking plants for their suitability in waste management systems, we need to have the following information:

1. Water requirement, removal capability, and tolerance.
2. Nutrient requirement, chemical removal capability, and tolerance, especially to metals and other micronutrients.
3. Soil conditions needed for effective growth and plant tolerance to salinity and acidity.
4. Season of growth, longevity, and dormancy periods of plants.
5. Effect of wastes on plant quality for marketing. Waste management systems, for example, may not be suitable for producing leaf vegetables. Crops produced with effluent must be thoroughly disinfected or washed before human consumption.
6. Tolerance to diseases that may be caused by wastes. For example, bermudagrass uses large amounts of NO_3-N, and buildup of NO_3-N in reed canarygrass is relatively slow. These qualities make the possibility of NO_3 poisoning of animals grazing the plants remote. But large applications of waste material on tall fescue and ryegrass cause NO_3 buildup and, thus, poisoning in animals grazing these plants. Plants also vary in tolerance to sodium and pH, which may be affected by applications of waste material on land.
7. Suitability for different cultural and crop management systems. In double cropping, for example, the total uptake of waste ingredients by plants certainly increases. Plants must also fit into crop management systems required by a land operator to achieve his particular economic goals.

2. UPTAKE AND MOVEMENT OF CHEMICAL ELEMENTS BY PLANTS

Of the components of wastes applied to the land, chemical elements have the greatest environmental implications. Fortunately, most of these elements (in varying amounts) are necessary for plant growth.

Waste management must balance the capacity of plants to take up chemical elements against amounts present in the wastes applied to the land. Either a lack or an excess of these chemicals can cause deficiencies in plant growth. An excess can also cause toxicity. Key requirements in any waste management plan are to apply nutrients in quantities that benefit plants and to provide a repository for nonessential compounds.

Plants require some 16 chemical elements. They get carbon and oxygen from the air and hydrogen from soil water. Nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium are needed in large quantities and are taken from the soil solution. Iron, manganese, zinc, boron, copper, chlorine, and molybdenum are needed in smaller amounts. These also come from the soil solution. Other elements may be taken up by the plant from the soil solution, sometimes with benefit, sometimes with detriment. Sodium taken up by a plant may exert a minor effect on potassium so that less K is needed. Excess sodium in the soil solution, however, may retard plant growth. Silicon is taken up and incorporated into the cell walls of grasses. Silicon promotes vigor and resistance to disease and drought in several grasses. Cadmium stimulates growth of certain grasses, especially creeping bentgrass. Cobalt is needed by nitrifying bacteria on clover roots. But an excess of any micronutrient damages plants.

Plants differ in their capacity to absorb nutrients from the soil. Some of these differences are genetic in origin and are associated with physical distribution and chemical characteristics. Almost any element in the soil solution is taken into the plant to some extent, whether needed or not. An ion in the soil goes from the soil particle to the soil solution, through the solution to the plant root, enters the root, and moves from the root through the plant to the location where it is used or retained.

The process of mineral uptake by plants is complex and our knowledge of it incomplete. Some of the known points are: (1) The process is not the same for all plants nor for all minerals. (2) The complete process occurs in a healthy root system supplied by carbohydrate and oxygen; the process is not complete if roots are destroyed by disease, starved from excess mowing, or smothered by excess water or compaction. (3) The necessary minerals must be available in the root zone in suitable amounts. (4) Uptake varies from mineral to mineral (table 6-1).

3. MOVEMENT AND REACTION OF KEY PLANT NUTRIENTS IN SOIL

Generally, five things can happen to elements in waste materials applied to land. They can (1) be used by the crop, (2) become part of the soil, (3) leach downward through the soil, (4) be washed away by erosion, or (5) volatilize and escape as a gas.

NITROGEN

Nitrogen is the only element entering to a significant extent into all five possibilities. Nitrogen fertilizer may occur as free ammonia, urea, ammonium, and nitrate. All forms of nitrogen applied to land usually are converted to nitrates. A plant is not affected by the source,

inorganic or organic, of nitrate or ammonium ions. Much of the nitrogen in waste management systems is from organic sources.

An important point is that NO_3 moves freely in the soil water because it is adsorbed on soil particles weakly or not at all. Thus irrigation, which is usually associated with waste management systems, presents a problem or dilemma--to provide enough nitrogen in the root zone for efficient crop growth without risking its excessive leaching from the soil.

Volatilization also occurs in the soil through biological reduction of nitrate to nitrous oxide, elemental nitrogen, and possibly nitric oxide. Thirty percent of nitrogen applied may be lost through volatilization. Actually, insofar as nitrogen is concerned, this gaseous disposal is not a disadvantage in waste management systems because more nitrogen can be applied than will be used in plant growth.

PHOSPHORUS

The chemical forms of phosphorus generally are more complex than those of nitrogen. Phosphate fertilizers added to the soil break down and react quickly to form dozens of new compounds. Phosphorus does not move appreciably in the soil unless the soil is washed away by erosion. In one experiment phosphorus applied to a soil moved no more than 8 inches in 50 years. Movement may be much greater in sandy soils and peat. But if the lower horizons have more clay, downward movement virtually stops. Thus, phosphorus leaching usually presents few problems in waste management systems. Even if some forms of phosphorus are fixed or tied up, plants take up the phosphorus they need if there is enough phosphorus in the soil.

POTASSIUM, CALCIUM, AND MAGNESIUM

Potassium, calcium, and magnesium have similar reactions in soil. Upon dissolution, each produces cations that are attracted to negatively charged, minute particles of clay and organic matter. Potassium is much less mobile than nitrogen but more so than phosphorus. Leaching losses of potassium generally are insignificant except in sandy soils. Calcium and magnesium may occur in drainage water but this creates no problem.

SULFUR

Part of the sulfur applied to well-drained soils ends up in sulfate form. Sulfates are moderately mobile and may be adsorbed on clay minerals. Under irrigation in waste management systems, sulfates may be leached into the subsoil and even into ground water. Under poor drainage conditions, sulfates are converted to hydrogen sulfide and lost to the atmosphere.

MICRONUTRIENTS

Boron, copper, iron, manganese, molybdenum, and zinc are fairly immobile in soils. Boron may be leached from sandy soils. Copper, iron, and

Table 6-1.--Plant nutrient uptake by specified crops[1/]

Crop and yield	N	P_2O_5	K_2O	Mg	S
			Pounds per acre		
Corn:					
180 bu grain	170	70	48	16	14
8,000 lb stover	70	30	192	34	16
Cotton:					
1,500 lb lint and 2,250 lb seed	94	38	44	11	7
Stalks, leaves, burrs	86	25	82	24	23
Wheat:					
80 bu	144	44	27	12	5
8,000 lb straw	42	10	135	12	15
Oats:					
100 bu	80	25	20	5	(2/)
Straw	35	15	125	15	(2/)
Barley:					
100 bu	110	40	35	8	10
Straw	40	15	115	9	10
Rice:					
7,000 lb grain	77	46	28	8	5
7,000 lb straw	35	14	140	6	7
Grain sorghum:					
8,000 lb grain	120	60	30	14	22
8,000 lb stover	130	30	170	30	16
Sugar beets:					
30 tons roots	125	15	250	27	10
16 tons tops	130	25	300	53	35
Sugarcane:					
100 tons stalks	160	90	335	40	54
Tops and trash	200	66	275	60	32
Tobacco (flue-cured):					
3,000 lb leaf	85	15	155	15	12
3,600 lb stalks, tops, suckers	41	11	102	9	7
Tobacco (burley):					
4,000 lb leaf	145	14	150	18	24
3,600 lb stalks, tops, suckers	95	16	114	9	21
Soybeans[3/]:					
60 bu	252	49	87	17	12
7,000 lb stalks, leaves, pods	84	16	58	10	13
Peanuts[3/]:					
4,000 lb nuts	140	22	35	5	10
5,000 lb vines	100	17	150	20	11

Table 6-1.--Plant nutrient uptake by specified crops--Continued

Crop and yield	N	P_2O_5	K_2O	Mg	S
			Pounds per acre		
Coconuts:					
3,600 nuts + 12 fronds lost annually..	75	25	120	20	12
Apples:					
600 boxes (42 lb)	20	8	50	2	(2/)
Blossom, fruit, new wood	80	38	130	22	(2/)
Peaches:					
600 bu	35	10	65	(2/)	(2/)
Tree annually	60	30	55	(2/)	(2/)
Grapes:					
12 tons fruit	66	23	120	(2/)	(2/)
Vines	36	12	36	(2/)	(2/)
Oranges:					
600 boxes (90 lb)	90	23	162	10	7
Trees (70/acre)	175	32	168	28	21
Tomatoes:					
40 tons fruit	144	67	288	10	28
4,400 lb vines	88	20	175	26	26
Potatoes:					
500 cwt	150	80	264	12	12
Vines	102	34	90	20	12
Celery:					
75 tons tops	255	130	680	(2/)	(2/)
Roots	25	35	70	(2/)	(2/)
Sweetpotatoes:					
400 bu	53	26	126	5	(2/)
Vines	50	14	84	6	(2/)
Cabbage:					
35 tons	(2/)	35	128	9	64
23 tons stem and leaf	(2/)	28	121	27	(2/)
Snap beans:					
4 tons	70	21	77	8	(2/)
Plants	68	12	86	9	(2/)
Table beets:					
25 tons roots	170	30	210	30	13
20 tons tops	190	13	370	74	28
Flax:					
30 bu	76	20	16	7	4
2,100 lb straw	19	5	44	6	5
Cucumbers:					
10 tons	40	14	66	4	(2/)
Vines	50	14	108	21	(2/)

Table 6-1.--Plant nutrient uptake by specified crops--Continued

Crop and yield	N	P_2O_5	K_2O	Mg	S
			Pounds per acre		
Peas:					
3 tons	45	9	17	8	(2/)
Pods and vines	105	17	62	14	(2/)
Onions: 30 tons	180	80	160	18	37
Lespedeza3/: 3 tons	150	50	150	25	20
Johnsongrass: 12 tons	890	190	630	60	50
Paragrass: 12 tons	308	98	460	79	41
Napiergrass: 12.5 tons	303	147	605	63	75
Guineagrass: 11.5 tons	288	101	436	99	46
Bluegrass (turf): 3 tons	200	55	180	20	25
Tall fescue: 3.5 tons	135	65	185	13	(2/)

1/ From Potash Institute of America. Plant food utilization. Atlanta, Ga. 1973.

2/ Figures unavailable.

3/ Legumes get most of their nitrogen from the air.

zinc move less than 1 inch from the point of application in most soils.

The data in tables 6-1 and 6-2 indicate the effectiveness of specified plants in uptake of chemical elements.

4. EFFECT OF FIELD CROPS, VEGETABLES, GRASSES, AND LEGUMES IN NEUTRALIZING WASTES

Crops have been grown for centuries on land also used for spreading manure and sewage. These materials were long regarded as fertilizers, not wastes, and no one considered that their use posed any problems of crop selection and management. Animal manure was spread on food and feed crops at the rate of a few tons per acre. Sewage and human waste were less often used, particularly in Western countries; but many cities spread sewage, with or without primary treatment, on land used for crops.

Although effluent and sludge have been applied on many kinds of grasses, vegetables, legumes, field crops, and woody plants, grasses seem to be the most effective in neutralizing wastes. Grasses are superior "biological pumps;" many species have a high water use factor combined with abundant root production. Grass roots and sod retard runoff and improve infiltration, and plant leaves transpire water back into the atmosphere. The effectiveness of pastures has been demonstrated many times.

Table 6-2.--Probable available form, average composition (range), and suggested tolerance level for heavy metals in selected agronomic crops monitored[1]

Metal	Probable available form	Average composition[2] (range)	Suggested tolerance level[3]
			ppm
		CATIONS	
Barium	Ba^{++}	10-100	200
Cadmium	Cd^{++}	0.05-0.30	3
Cobalt	Co^{++}	0.01-0.30	5
Copper	Cu^{++}	3-40	150
Iron	Fe^{++}	20-300	750
Manganese	Mn^{++}	15-150	300
Mercury	Hg^{++}	0.001-0.01	0.04
Lithium	Li^{+}	0.2-1.0	5
Nickel	Ni^{++}	0.1-1.0	3
Lead	Pb^{++}	0.1-5.0	10
Strontium	Sr^{++}	10-30	50
Zinc	Zn^{++}	15-150	300
		ANIONS	
Arsenic	AsO_4^{--}	0.01-1.0	2
Boron	HBO_3^{--}	5-75	150
Chromium	CrO_4^{--}	0.1-0.5	2
Fluorine	F^{-}	1-5	10
Iodine	I^{-}	0.1-0.5	1
Molybdenum	MoO_4^{--}	0.2-1.0	3
Selenium	SeO_4^{--}	0.05-2.0	3
Vanadium	VO_3^{-}	0.1-1.0	2

1/ From Melstad, S.W. Some practical considerations in waste management. Univ. Ill. Dep. Agron. July 1973.

2/ Average values for corn, soybeans, alfalfa, red clover, wheat, oats, barley, and grasses grown under normal soil conditions. Greenhouse values (both soil and solution) are not included.

3/ Values are for corn leaves at or opposite and below ear level at tassel stage, the youngest mature leaves and petioles on soybean plants after first pod formation, upper stem cuttings of legumes in early flower stage, whole cereal plants at boot stage, and whole grass plants at early hay cutting stage.

In many waste management systems, plants are used successfully to recycle effluent and sludges on land. Some examples follow.

Berlin's sewage farm was started about 1850; by 1905 it covered 21,000 acres and supplied one-fourth of the vegetables for the city's population. Paris established its first sewage farm in 1870. Both these cities, and many others in Europe, grow vegetables, tree fruits, cereals, and forage crops. Werribee Farm in Melbourne, Australia, began operation in 1893 and since then has produced 266,000 cattle and nearly 1.5 million sheep on pastures irrigated and fertilized with sewage.

Pasadena, Calif., started a sewage farm in 1887; by 1935 90 of the 310 municipalities in California were spreading sewage on land. Vegetables, fruit trees, grapes, alfalfa, sugar beets, hops, and cotton were grown; only salad vegetables and berries were forbidden. San Antonio, Tex., started using waste materials in 1915 for growing corn, grain sorghum, cotton, forage, pecans, citrus, vegetables, and roses for cut flowers.

Pleasanton, Calif., a city of 7,000 people, annually disposes of 370 million gallons of effluent on about 85 acres of pasture. Forage includes several mixtures of grasses and legumes. Ryegrass (Lolium spp.), orchardgrass (Dactylis glomerata), and hardinggrass (Phalaris tuberosa stenoptera) are the grasses commonly used in the pasture mixtures. Annual application is 13 to 14 acre-feet. Current application is about 1 acre-foot per day in a 30- to 35-day rotation. Beef cattle graze continuously throughout the year. The effluent applied to this pasture contains the equivalent of 400 lb nitrogen per acre per year, more than 200 lb phosphorus per acre per year, and more than 500 lb potassium per acre per year. Grasses in waste management systems should be kept properly grazed or mowed. Water use and chemical uptake by plants are greater when plants are succulent and growing.

At Oregon State University, 15,000 gal liquid manure are pumped daily onto a 60-acre 'fawn' fescue (Festuca arundinacea) pasture. It is estimated that 60 tons per acre of manure, including bedding, is applied each year. Contained in this liquid manure are 660 lb nitrogen per acre, 130 lb phosphorus per acre, and 500 lb potassium per acre. The annual volume of liquid manure applied to pasture is 5.5 Mgal (17 acre-ft).

Experience with heavy rates of waste application on grass and legume pasture by Washington State University contrasts with the Oregon State University results. Irrigation with liquid manure containing as much as 9 percent solids heavily coated the leaves of legume plants and stifled their growth. But ryegrass, because of its narrow leaves and upright growth habit, performed well under the heavy loading. Legumes, which have broad leaves, are less effective in waste disposal systems than grasses.

Bermudagrass (Cynodon spp.) can use large amounts of nitrogen. In Arizona 40 to 60 tons per acre of dry manure were applied on 1,000 acres of irrigated pasture consisting of bermudagrass for warm-season grazing and overseeded ryegrass for winter grazing. No critical nitrate levels have been found in this operation.

In Florida, the annual nutrient uptake per acre for coastal bermudagrass in summer (March to November) was 570 lb N, 145 lb P_2O_5, and 400 lb K_2O. For ryegrass overseeded in winter (December to March), the annual nutrient uptake per acre was 205 lb N, 75 lb P_2O_5, and 135 lb K_2O.

In experiments in the Southeast, no nitrate poisoning has resulted from grazing bermudagrass fertilized with chicken litter at 20 tons per acre per month during the growing season. At 40 lb nitrogen per ton of chicken litter, 5,600 lb nitrogen per acre are applied during a 7-month season. These findings contrast with those from tall fescue pasture in Nevada. When harvested as hay, tall fescue fertilized with 16 tons per acre of chicken litter in September contained 0.6 percent nitrate, enough to induce poisoning and cause grass tetany. The Agricultural Research Service (ARS) has determined that 5 tons per acre per month of chicken litter is detrimental.

In California, chicken litter has been successfully used on vegetables, strawberries, irrigated pasture, and annual dryland grass range. On annual grass range, forage yields increased by 1,600 lb per acre for each ton of litter applied. The practical upper limit was found to be 4 tons per acre. Above this rate yields increased only slightly or were depressed.

At the Board of Works Farm in Melbourne, Australia, almost 14,000 acres of permanent pasture are irrigated by waste water. The land is planted to mixtures of grasses to provide a balanced pasture throughout the year: perennial ryegrass (*Lolium perenne*), Italian ryegrass (*Lolium multiflorum*), white clover (*Trifolium repens*), strawberry clover (*T. fragiferum*), alsike clover (*T. hybridum*), orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), and meadow fescue (*Festuca elatior*). During the peak of the irrigation season, water is applied to pasture at a rate of 220 acre-feet a day or 2 inches per acre per week. In a typical summer, the total quantity used for grass production is about 34,000 acre-feet.

Reed canarygrass (*Phalaris arundinacea*), with its high water requirement and rhizomatous growth, has proved effective in waste management systems. In Pennsylvania State University research, reed canarygrass was effective in removing nitrogen. In 1965-1970, harvested reed canarygrass removed 2,073 lb nitrogen per acre, equivalent to 86 percent of the nitrogen in 536 inches of applied effluent. Nitrate buildup in reed canarygrass is extremely slow, making nitrate poisoning a remote possibility. Total hay cuttings per year resulted in nitrate content below the acceptable level of 1,500 ppm. Reed canarygrass has also controlled the leakage of nitrates into ground water. In the Penn State University studies, the nitrate nitrogen (NO_3-N) leakage ranged from 2.8 mg/l in 1965 to 2.2 mg/l in 1970. The limit recommended for drinking water by USPHS is 10 mg/l nitrate nitrogen or 45 mg/l nitrate. However, the nitrate nitrogen in ground water under corn silage exceeded the USPHS limits. This excess was caused by late-season planting and earlier harvesting periods that avoid nitrogen buildup in the soil. No-till planting might help solve this problem.

On a private dairy farm in Chester County, Pa., 7.5 acres were seeded in 1970 to sudangrass (*Sorghum vulgare sudanense*) for green chop. From July to frost, five cuttings were harvested. In 1971, rye (*Secale cereale*) was seeded before sudangrass and planted again after the last sudangrass harvest in the fall. This system certainly increased the total chemical uptake by the plants.

In a University of Maryland study, Kentucky bluegrass (Poa pratensis), ladino clover (Trifolium repens), and strawberry clover (T. fragiferum) were found to tolerate heavy irrigations of waste material.

In the Illinois Shawnee National Forest, a one-time application of 121 tons of dry sludge per acre produced a healthy stand of weeping lovegrass (Eragrostis curvula) on surface-mined areas. Water quality measurements over 1 year revealed that concentration of iron declined 81 percent; aluminum, 86 percent; manganese, 67 percent; sulfate, 61 percent; and acidity, 76 percent. Plans are to apply 200 tons (dry weight) of sludge per acre through sprinkler irrigation systems.

In a Florida University study, oats, rye, and ryegrass are being produced during the winter with sewage effluent. Sorghum, kenaf, corn, millet, and coastal bermudagrass are grown in summer. Another study showed a 240 percent increase in napiergrass (Pennisetum purpureum) and Japanese cane when effluent was used to irrigate these crops.

At the Pratt Feedlot in Kansas (33,000 head on 220 acres), an average of 1,000 lb dry manure per animal per year is recovered. In 1969, this manure contained 20 lb nitrogen per ton. Yields of corn for silage were 23.2 tons per acre from an optimum application of 103 tons of manure (2,060 lb N per acre). Rates of application ranged up to 320 tons. The optimum annual application, however, may be considerably less than 100 tons per acre per year, considering the additive effects that may occur. Nitrate levels were less than 0.03 percent and no threat to livestock. The maximum tolerance for nitrates in forage is 0.15 percent.

5. EFFECT OF TREES AND FORESTS IN NEUTRALIZING WASTES

Forested areas provide a feasible medium for recycling agricultural wastes on land. In the Penn State waste water renovation and conservation project, effluent was applied on forest and cropland. The first stage of waste-water renovation in the forested areas occurred during passage of effluent through the forest floor. Percolation through the upper 4 feet of soil further increased the renovation. The disposal site had a native mixed oak stand consisting primarily of white oak (Quercus alba), black oak (Quercus velutina), red oak (Q. rubra), and scarlet oak (Q. coccinea). Ground vegetation consisted mostly of blackcap raspberry (Rubus occidentalis), blueberry (Vaccinium spp.), teaberry (Gaultheria procumbens), violet (Viola spp.) and wildsarsaparilla (Aralia nudicaulis). The forest floor had a layer of about 1.5 inches of organic matter, much of which was well-developed humus.

Results showed that over a 6-year period the forested areas were efficient removers of chemical components. Phosphorus concentration at the 2-foot soil depth was reduced by 98 to 99 percent. Nitrate concentration was reduced 68 to 82 percent at the 12-inch soil depth. Continuous irrigation of effluent could become a major problem because of excessive nitrates. This may deter long-term use of forested areas unless biodenitrification processes are promoted.

At the Seabrook Farms in New Jersey, annual applications of effluent on areas of white and black oak were 400 to 600 inches over an 8-month period. A few isolated areas received as much as 800 to 1,000 inches. After 7 years, hydrophytic plants replaced native trees and shrubs,

forming a thick carpet of decaying vegetation. Although forest cover was eliminated, waste water continued to be satisfactorily renovated with no adverse effects on ground-water reservoirs.

In a study at Grand Mere plantations, Quebec (reported by J. D. Gagnon, Canadian Forest Service), white spruce was the test tree. Digested sludge was applied at 500 lb per acre (dry weight). The plantation on a sandy soil gave a 30 percent height-growth response over control trees after 4 years. The researchers of this project feel that digested sludge can be used successfully as a fertilizer to increase tree growth.

Considerable amounts of nutrients are taken up by trees in forested areas. Many of these nutrients are redeposited annually in leaf and needle litter and are not removed as are those in harvested agronomic crops. Waste management systems can often be operated continuously throughout the year. In northern climates where much freezing occurs, waste management must rely more on the absorptive capacity of the soil and less on microbes and plant roots.

Because of the acid condition of the soils, forested areas during winter provide better infiltration conditions and larger phosphorus-adsorptive capacity than croplands and grasslands do. Some ice buildup may occur, but there is no serious damage. Thus, a combination of cropland, grassland, and forests provide much flexibility in operating a waste management system on land.

6. REMOVAL EFFICIENCY

Dr. L. T. Kardos of Pennsylvania State University expresses the capacity for chemical uptake by plants as "renovation efficiency," which essentially is a ratio of the weight of nutrient removed in the harvested crop to the weight of the same nutrient applied in the waste water. For example, in one experiment (1965) in which effluent was applied at the rate of 1 inch per week, corn silage removed nutrients equivalent to 202 percent of the total nitrogen applied, 39 percent of the phosphorus applied, and 62 percent of the potassium applied. Even at the 2-inch per week level, corn silage removed the equivalent of 103 percent of the nitrogen applied.

Since there is great diversity in the composition of waste material, crop tolerance, and soil and climatic conditions, it is not possible to make specific crop and management recommendations. The lack of information on long-term effects of waste disposal on land is also a hindrance.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 7. GEOLOGIC CONSIDERATIONS IN WASTE MANAGEMENT

Compiled by Alfonso F. Geiger, engineering geologist, SCS, Washington, D.C.

Surface indicators cannot be relied upon to disclose accurately the nature of the geologic environment for any given waste management site. Adverse effects of waste application on or beneath the ground surface can be transmitted far beyond the site if certain conditions prevail. A common adverse effect is the pollution or degradation of surface or ground waters by chemical or biological components of leachates or liquid wastes.

Waste management sites are normally chosen on the basis of the ability of the soils and plant cover to absorb and renovate wastes. But subsurface conditions may be such that, through highly permeable lenses, joints, cracks, or solution channels, the waste liquids totally or partially bypass the soil and are transmitted directly to ground or surface waters.

Land that resists mass movement under natural conditions may become unstable under heavy application of liquid wastes. This can happen in sloping areas underlain by shale or certain other materials that are less permeable than the overlying soils.

Poisonous, explosive, or odoriferous gases have been transmitted through sand lenses and buried channels considerable distances from sanitary fills. While this transmittal of gases may be an uncommon problem, it is exceptionally difficult to correct once it happens.

Generally, under continuous operation the maximum rate of application of liquids to the ground surface is controlled by the least permeable stratum between the surface and the water table or by the depth to the water table. If subsurface materials are not as permeable as surface ones or if the water table is shallow, the liquids from heavy application infiltrate, reach the less permeable layer or saturated zone, spread laterally, and build up a ground-water mound or a perched or semiperched water table. The mound or perched water table thus formed may reach to the ground surface, causing waterlogging and surface runoff. In effect, usefulness of the system is diminished or eliminated.

Lagoons or holding ponds must be investigated for potential seepage losses and to evaluate sealing procedures if they are needed. Ponds with seemingly impermeable bottoms often fail if they overlie rocks containing solution channels or open joints or bedding planes. Failure is through piping and may be sudden and catastrophic, resulting in widespread surface and subsurface pollution. Concrete holding tanks have failed because of undermining resulting from small leaks with subsequent soil piping into rock voids.

To evaluate the geologic considerations for a given waste management practice, the following questions should be answered:

1. What is the thickness of unconsolidated material?
2. What is the nature of any material between the soil and bedrock--stratification, structure, permeability, texture, etc.?
3. What is the nature of the bedrock--rock type, structure, dip and strike, permeability, etc.?
4. Is the rock jointed, fractured, open bedded, or otherwise altered? If so, what is the size and attitude of the openings and are they enlarged by solution?
5. Do either rock or unconsolidated, confined, or unconfined aquifers exist at the site, and what is their depth and permeability? Usually estimates of permeability are adequate, with emphasis on relative permeability of the various strata. If flow computations are to be made, field permeability tests are necessary.
6. What are the seasonal changes in ground-water levels, and when do the minima and maxima occur? What about permanent or ephemeral springs or seeps?
7. What is the direction and rate of ground-water movement (slope of water table or piezometric surface)?
8. What is the present quality of the ground water?
9. What will be the quality of any waste water or leachate reaching the ground water?
10. What are the projected long-term effects on the quality and future use of the ground water?
11. Does potential for mass movement exist at this site? Do landslides occur in the area and, if so, is their cause (causes) understood?

With answers to these and other questions that apply to a given situation, and with a geologic analysis, impact of a waste management practice on the environment can be better understood and evaluated.

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CHAPTER 8. FISH AND WILDLIFE ASPECTS OF WASTE MANAGEMENT

Compiled by L. D. Marriage, biologist, SCS, Portland, Oreg.

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CHAPTER 8. FISH AND WILDLIFE ASPECTS OF WASTE MANAGEMENT

1. GENERAL

Wildlife depend on the extent and quality of their habitat. Health of animals, their number, and their kind are indices of change in quality of the habitat. Reduction in number or disappearance of a species from an area may be an indication of pollution.

Changes in habitat quality can come about through natural processes such as geological erosion and plant succession or be man induced through any of a number of activities such as reservoir construction, intensive land use, land clearing, deforestation, and poor agricultural practices. Any ill-advised, poorly planned, and single-purpose oriented activities can be deleterious and even disastrous. Conversely, man's activities that are properly planned and carried out can bring about beneficial changes in wildlife habitat.

2. AQUATIC HABITAT

Wildlife species requiring aquatic habitat include fish, amphibians, molluscs, crustaceans, and certain insects. All require specific kinds of food, cover, and water quality. Requirements vary from one species to another and result in the occupation of a variety of niches in the aquatic habitat. Some common causes of pollution and other factors relating to aquatic habitat are explained in the paragraphs that follow.

Some agricultural activities (use of pesticides and fertilizers and manure-silage drainage) in the United States resulted in 1.8 million fish killed in 1970.[1/] For the second year in succession, wastes from Kansas livestock feedlots accounted for the majority of that state's pollution-caused fishkill in 1972.

Improperly applied irrigation water flows over the soil surface, picking up plant stains and carrying in suspension fine clay particles and silt into streams, lakes, and reservoirs. Excessive amounts of silt smother small fish, eggs, and food organisms. Silt can cover spawning beds and cause turbidity. Turbidity reduces sunlight penetration, makes it difficult for fish to find food, and retards growth of phytoplankton, an essential element of the aquatic food chain.

Waste water from irrigated land picks up organic matter and carries it into streams and ponds. The decomposition of this material may cause oxygen deficiency, which can severely harm fish.

Irrigation water may also pick up residues of pesticides, fungicides, or herbicides. These residues have a toxic or lethal effect on fish, and may also harm other animals and human beings. Minimal use of persistent

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[1/] EPA Office of Water Programs. Fish kills caused by pollution in 1970, 11th annual report. 24 p. 1972.

pesticides and other chemicals and the development of shorter lived ones are desirable.

Much has been written about eutrophication, most of it in condemnation. However, eutrophication is a natural process involving the conversion of waterborne nutrients to biomass, whether plant or animal. Eutrophication results in a gradual accumulation of sediment and organic matter that eventually cause a pond or lake to fill and become a marsh. The process may take several decades or several hundred years, depending on the size and configuration of the body of water and the nutrient level. If the nutrient level is excessive, as it may be when mineral or organic fertilizers from agriculture enter the pond or lake, the process is speeded up and often results in a deficiency in dissolved oxygen, generation of hydrogen sulfide gas, and fishkills. Controlling the use of mineral fertilizers in warm-water fishponds combined with correct dam design and proper management can result in an increased yield of usable fish and a smaller aquatic plant community. Thus controlled and managed for wildlife, eutrophication can be a beneficial use of resources.

Alteration of water temperature is another agriculture-related form of pollution. Land treatment, pond and reservoir construction, reduction of water depth and widening of streams, removal of streamside vegetation, and irrigation are examples of activities that may affect water temperature and increase sediment loads of aquatic habitat. A rise in water temperature decreases water's ability to absorb oxygen; increases metabolism, respiration, and oxygen demand of fish and other aquatic life; intensifies the toxicity of many substances; and favors the growth of undesirable kinds of algae, fungi, and bacteria. These changes can alter the composition of the aquatic community.

Conservation measures on land that help to maintain or create proper water temperatures for fish include minimum tillage, grassed waterways, streambank protection, and proper grazing use.

The use of chemicals for fish culture is restricted by the expensive documentary research necessary for federal registration. The chemicals that are registered for use in fish culture are several piscicides--Antimycin-A, Fintrol-5, and rotenone; food additives--sulfamerazine and Terramycin; a tranquilizer--tricaine methanesulfonate (MS-222); and the algaecides--copper sulfate and copper triethanolamine (Cutrine).

Some selected habitat and life history parameters are given in table 8-1.

3. SEMIAQUATIC HABITAT

Semiaquatic wildlife habitat supports animals that may depend for survival on both terrestrial and aquatic environs. Marshes, wetlands, bogs, and swamps are examples. These areas support such animal species as waterfowl, shore birds, and some furbearing mammals.

Semiaquatic areas are affected by agriculture-related pollutants in much the same way that aquatic and terrestrial areas are. They can be reduced in value or physically destroyed by sediment, pesticides, changes in salinity, and excessive nutrients. Mud-covered grass and debris-filled marshes remain unattractive to animals for a long time. Pesticides can be disastrous to food organisms and to desirable species. Increases

Table 8-1.--Parameters for representative aquatic habitat

Parameter	Cold-water fish (trout)	Warm-water fish (bass, bluegill, channel catfish)
Water temperature .... °F..	50-65 necessary for optimum growth; 32-50 and 65-75 result in slow growth; 46-55 necessary for optimum egg incubation and hatching; 86 is lethal level.	65-95 necessary for optimum growth; 60-70 results in slow growth; 60 results in little or no growth.
Dissolved oxygen ....ppm..	5 is minimum requirement; saturation desirable; 7 necessary for egg incubation and hatching.	3 is minimum requirement; saturation is desirable.
Hardness (as $CaCO_3$) ....ppm..	50-250 is desirable	50-200 is desirable.
pH	6.0-8.0 is desirable; 4.5 and 10.0 are extremes.	6.5-8.5 is desirable for growth and reproduction; <4.0 is lethal level <5.0 results in no spawning; 5.0-6.5 results in slow growth.
Turbidity ....JTU[1/] ..	$\leq$ 10 is desirable	$\leq$50 is desirable.
Carbon dioxide (free CO_2) ....ppm..	25 is maximum requirement.	25 is maximum requirement.
Hydrogen sulfide ....ppm..	< 1.0 is maximum requirement.	< 1.0 is maximum requirement.
Chlorinated hydrocarbons ...mg/l ..	0	0.
Nitrates ....ppm..	< 5.0	5.0.
Phosphates ....ppm..	< 500 during 24-hour exposure.	(?)
Potassium[2/] ....ppm..	50 is lethal level for stricklebacks; 0.4-1.5 is natural in oligotrophic and mesotrophic lakes; 5-6 is natural in very eutrophic lakes.	

[1/] Jackson turbidity units.

[2/] The potassium toxicity level for Amphipod (Gammarus) crustaceans is 200 ppm; for such insects as the Chironomidae, 700 ppm; and for such insects as the Trichoptera, 1,000.

in salinity may kill food plants, thus reducing the number of seed-eating birds. Most waterfowl can use water with salinity as high as that of seawater, 35,000 ppm. Excessive nutrients may cause excessive algal growth, putrefaction, oxygen deficiency, formation of hydrogen sulfide gas, and the like.

Tolerance of selected waterfowl plant foods to different levels of salinity is given in table 8-2. Tolerance of other crops is given in chapter 4 (figs. 4-1a, 4-1b, and 4-1c and table 4-1) of Section 16 of the National Engineering Handbook (NEH).

Table 8-2.--Salinity tolerance of some waterfowl foods

Common name	Scientific name	Salinity tolerance range
		Parts per million
Most pondweeds	Potamogeton spp.	0 - 1/1,000
Watershield	Brasenia schreberi	0 - 1/1,500
Common duckweed	Lemna minor	0 - 1/2,000
Barnyardgrass	Echinochloa crusgalli	0 - 2/3,500
Common spikerush	Eleocharis palustris	0 - 2/4,000
Arrowhead	Sagittaria calycina	0 - 2/4,000
Common sunflower	Helianthus annuus	0 - 1/4,000
Reed canarygrass	Phalaris arundinacea	0 - 1/4,000
Smartweeds	Polygonum spp.	0 - 1/4,000
Corn	Zea mays	0 - 1/4,500
Common oat	Avena sativa	0 - 1/5,000
Chufa	Cyperus esculentus	0 - 1/5,000
Wheat	Triticum aestivum	0 - 1/5,000
Narrowleaf cattail	Typha angustifolia	0 - 1/5,000
Rye	Secale cereale	0 - 1/5,500
Dallisgrass	Paspalum dilatatum	0 - 1/6,000
Rice	Oryza sativa	0 - 1/6,500
Niad	Najas spp.	0 - 1/6,500
Fennelleaf pondweed	Potamogeton pectinatus	0 - 1/7,000; 2/9,500
Nuttall alkaligrass	Puccinellia nuttalliana	0 - 3/7,500
Barley	Hordeum vulgare	0 - 1/10,000
Bermudagrass	Cynodon dactylon	0 - 1/10,000
Bearded sprangletop	Leptochloa fascicularis	0 - 1/10,500
Olney bulrush	Scirpus olneyi	0 - 2/10,500; 4/20,000
Common poolmat	Zannichellia palustris	0 - 2/12,000
Cattail	Typha domingensis	0 - 1/10,000; 2/12,000; 4/25,000
Seashore saltgrass	Distichlis spicata	0 - 1/12,000+; 4/35,000
Dwarf spikerush	Eleocharis parvula	1,000 - 1/10,000
Hardstem bulrush	Scirpus acutus	0 - 4/14,000
Alkali bulrush	Scirpus robustus	1,500 - 1/12,000; 2/20,000; 4/50,000
Nevada pondweed	Potamogeton latifolius	1,500 - 2/20,000
Annual atriplex	Atriplex patula	2,500 - 4/7,500
Chara	Chara spp.	4,000 - 2/20,000
Bird brassbuttons	Cotula coronopifolia	4,000 - 4/40,000
Widgeongrass	Ruppia maritima	5,000 - 1 2 5/45,000; optimum 2/10,000 - 20,000
Pickleweed	Salicornia virginica	5,000 - 2/45,000; 4/62,000; 6/81,000
Shoalgrass	Diplanthera wrightii	20,000 - 5/80,000

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4. TERRESTRIAL HABITAT

Certain terrestrial forms of wildlife depend on agriculture for survival. Others are more resourceful and can survive without agriculture, but in lesser numbers. Examples of wildlife common to farmlands are white-tailed deer, pheasant, valley and bobwhite quail, grouse, waterfowl, cottontails, and songbirds.

Terrestrial forms of wildlife are perhaps less affected by sedimentation than semiaquatic or aquatic species. Nests of young of ground-nesting bird species can be lost, however, if covered with sediment deposited by wind or water. Roadsides, used by nesting pheasants, bobwhites, songbirds, and cottontails, commonly have heavy sediment deposits.

Sediment deposited on bottom lands that support a wildlife food supply may cause the animals to forage elsewhere for cleaner and more palatable food. Thus, the indigenous wildlife population abandons the home range and is lost to it until palatable plants are again produced there. Such movements of animals usually result in heavy predation losses. Mud-covered grass and debris-filled thickets may remain unattractive to wildlife for a long time.

Terrestrial forms of wildlife can be unintended victims of agricultural pesticides. Ingested pesticide residues may accumulate and concentrate in body tissues in dangerous or lethal amounts. One result is that hatching success of nesting birds may be decreased by reduced thickness of egg shells. Furthermore, young pheasant chicks may be killed by breathing or dermal absorption of applied pesticides, and lower forms of organisms in the food chain may be eliminated by the pesticides, thus breaking the normal development of food-chain organisms and reducing the food supply of some wildlife.

Moderately saline drain water, 3,000 to 10,000 ppm, is unpalatable to most upland game species.

5. SUMMARY

Agricultural wastes have significant and variable effects on fish and other wildlife. Some of the bad effects are obvious. Scientists have recently begun to recognize the less obvious effects, some of which may require sophisticated testing and monitoring over a period of time. Planning for agricultural waste management should take into account maintaining the quality of all wildlife habitats: aquatic, semiaquatic, and terrestrial.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 9. LIVESTOCK AND POULTRY WASTE MANAGEMENT SYSTEMS

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PART I - BEEF CATTLE

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PART II - DAIRY CATTLE

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PART III - SWINE

Compiled by Philip H. Christensen, assistant state conservationist, SCS, Amherst, Mass.

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Compiled by Glenn E. Stucky, water management engineer, SCS, Broomall, Pa.

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Compiled by William F. Long, water management engineer (ret.), SCS, Portland, Oreg.

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CHAPTER 9. LIVESTOCK AND POULTRY WASTE MANAGEMENT SYSTEMS

PART I - BEEF CATTLE

1. GENERAL

The first step in planning a waste management system for a cattle-feeding enterprise is ascertaining where the cattle are to be fed--in confined housing, partially enclosed lots, or open facilities.

Confined housing may be either cold or warm confinement. Cold confinement housing consists of a surface lot or slotted floor completely under roof but not enclosed. Warm confinement housing means a completely enclosed building with insulation and regulated ventilation. In confined housing all the waste material is deposited inside the building, from which it must be collected and transported to a disposal area.

Partially enclosed lots generally consist of sheds open on one side. They provide shelter during severe weather or a resting area from direct sunlight. Part of the wastes are deposited within the shed and part in the open area.

Open feedlots may be earth lots or concrete-surface lots or a combination of the two. All wastes are deposited in the feedlot area.

2. SITE SELECTION

TOTAL CONFINEMENT SYSTEMS

The best location for total confinement housing depends on prevailing winds, slope, and convenience to water and feed supply. Because of potential odor, total confinement systems should be downwind and some distance from homes and businesses but not adjacent to streams.

PARTIALLY ENCLOSED AND OPEN FEEDLOTS

The best location for a feedlot depends on factors such as prevailing winds, adequate slope for drainage, convenience to water and feed supply, and adequate space for handling and storing the wastes. Feedlots should be on high ground away from both streams and populated areas and downwind from neighboring residences and businesses.

Lots should have a uniform slope away from prevailing winds. Slopes of 4 to 6 percent are common in the Midwest. Flatter slopes are quite common in other areas. Dirt mounds can be built in unpaved lots to provide dry areas and some shelter from cold winds. Because of potential ground-water pollution, feedlots should not be located near a sinkhole or abandoned well or on a site known to be underlain by fractured limestone.

3. SPACE REQUIREMENTS

A selected feedlot site should have adequate space for future expansion. A site adequate for a 1,000-head lot may not accommodate an increase to 5,000 head.

For both warm and cold confinement feeding, the maximum density is about 20 ft^2 per 1,000-lb animal for slotted floors and about 30 ft^2 per 1,000-lb animal for solid floors. Additional space should be provided for feeding areas and alleys. For feedlots in the Midwest, the following areas in square feet per head are commonly provided:

Unsurfaced lot	400
Partially surfaced lot	150
Surfaced lot, no shelter ...	55
Surfaced lot, open housing..	30

4. WATER DIVERSION

Water from outside sources should be kept from draining to lot areas and manure storage tanks, pits, or ponds. Diversions, waterways, and terraces should be used as drainageways for this unpolluted surface water. Buildings and feed bunk shelters should be equipped with gutters that discharge the roof water away from the feedlot and the manure pit or tank. Water collected by gutters can be carried under or around the feeding facility through underground pipelines or open channels.

Drainage problems inside the feedlot are minimized by proper slope away from buildings, self-feeders, and waterers. Suggested slope from feeders and waterers is 3/4 to 1 inch per foot; from buildings, 1/2 to 3/4 inch per foot; and along drainageways, 1/4 to 1/2 inch per foot. Floor slope of 1/4 to 1 inch per foot toward the open front is common in buildings. Recommendations vary, however, by sections of the country.

5. COLLECTION OF WASTES

GENERAL

The type of collection facilities for livestock waste depends on the amount and type of material to be collected. To the amount of waste excreted by beef cattle (estimated as about 0.14 ft^3 per 100 lb of weight) must be added the precipitation that runs off the area and the water, wasted feed, or other materials deposited in the facility. The waste product may be solid, semiliquid, or liquid.

CONFINED HOUSING

Manure deposited in confined housing is generally in semiliquid or slurry form. Buildings are generally designed for one of four methods of collection:

1. Slotted floors. Wastes collect in concrete tanks under the floor. If only part of the floor is slotted, some scraping may be required

2. Barn gutters with mechanical cable scrapers. Wastes collect in gutters and are moved by scrapers on a continuous cable mechanism to a collection pit at one end of the structure.
3. Barn gutters with hydraulic flushing. Water is used in place of the scrapers to carry the wastes to the pit at the end of the feeding structure.
4. Solid floors. A tractor-mounted scraper is used to push the wastes into a pit or a nearby storage area for further disposition.

The concrete tanks under slotted floors should be big enough to hold the waste for the intended storage time. The amount of waste can be estimated as about 0.14 ft^3 per 100 lb of animal per day. Tank space should be increased as necessary to allow for water to be added to the tank before and during storage. Allowance should also be made for unusable storage space such as the few inches at the bottom that cannot be pumped and the freeboard at the top. The tank may be designed to store the waste material until it can be spread on land. A storage period of about 90 to 180 days is common, depending on climate and location, periods when the ground is not frozen, or availability of a disposal area. Or, the tank may store only a week's collection or less, and the facility must have pumping equipment and a pipeline to transport the material to other storage facilities for future disposal.

A collection pit at one end of a confinement area normally should be emptied daily. If a mechanical cable scraper or tractor is used, the material is a thick slurry. If a hydraulic flushing system is used, the material is liquid and the volume handled depends on the amount of water added. In either situation, the material normally is pumped into a lagoon or storage facility for field disposal at a later time. Material collected by mechanical scrapers or tractor-mounted scrapers can be delivered by a conveyor. The tractor scraper is often used to shove the material over a reinforced concrete ramp into a storage facility.

FEEDLOTS

Wastes deposited on concrete-surface feedlots are usually of the same consistency as those deposited in confined areas. However, this material is subject to dilution from precipitation on the lot and to evaporation. The amount of manure in the runoff can be minimized by daily or at least weekly scraping of the paved lots. The manure can be either stockpiled or hauled directly to the field. Fly and other insect control is also needed in and around any buildings and manure storage areas.

Manure hauled directly to the field is usually loaded into the spreader by a tractor and scraper. A reinforced wall to push the manure against is convenient. In another method it is loaded directly into the spreader or storage facility from a scrape-off ramp at the end or side of the lot. Manure not hauled immediately to the field can be stored temporarily in a solid-floor holding area. Where there is area of 10 ft^2 per head, storage for about 10 days is possible.

Liquid runoff should be collected below the feedlot and carried to a holding pond or some other suitable disposal facility. A debris basin, as discussed in chapter 12, is necessary for settling out solids between the feedlot and the holding pond since cattle manure tends to rise to the surface and form a layer difficult to handle with conventional available equipment.

A settling basin with liquid runoff flowing directly to the fields may be all that is needed for some feedlots. But liquid runoff directly to the fields is possible only on fields that are away from streams, have little slope, and are heavily cropped.

Liquids (urine, rain, and melting snow) in waste material deposited on earth lots must be drained off and impounded to avoid comtamination of waterways. The liquids should be handled in the same manner as runoff from concrete-surface lots. Solids can be scraped into windrows and removed with loaders and spreaders or scraped into mounds to decompose and provide dry resting areas for cattle. When lots are scraped, some material can be left to act as a sponge for small rains. This sponge helps to minimize soil loss and maintain a relatively impermeable barrier against excessive infiltration into the soil.

Waste material deposited in lots with bedded sheds is about the same as that in lots without sheds, except that about half of the animal waste is in the manure pack. Any runoff from wastes deposited in lots can be stored in structures as discussed in chapter 12 and disposed of by land application as specified in chapter 11.

Examples of complete livestock waste management systems are given in the following pages. Components of one suggested system can be combined with those of another. All the components shown for each system may not always be needed. For example, in a liquid-manure system, the sprinkler equipment illustrated may or may not be needed, depending on the desired type of management. The system best suited to a given operation must be based on a thorough evaluation of all the physical and management factors. Table 9-1 lists typical manure handling system components for various beef feedlot operations. The size and shape of each component depends on individual system design.

6. LIQUID-MANURE SYSTEMS (Sample layouts)

HAULING

In a liquid-manure system wastes are collected in tanks. The tanks are emptied periodically, and the contents are spread on a utilization area. Major components of a hauling system are illustrated in figure 9-1 and described below.

1. Collection. The collection tank may be under a part or all of the building floor, or it may be outside the building. Tanks under buildings usually have slotted floors over them. Tanks built outside buildings should be covered to exclude rainwater, reduce safety hazards, minimize odor, and prevent fly breeding. The tank should generally be large enough to hold a 90- to 180-day accumulation of manure and waste water. Length of the

Table 9-1.--Manure handling systems for beef cattle

Type of animal management	Type of manure	Collection, transfer, and storage	Removal and transport to land	Comments
Open field and woodlot	Field droppings		Spread by livestock.	
	Manure near feeding-watering sites.	On slab or ground..	Tractor loader to spreader to land.	If slab not used at feed and water site, change site location periodically to minimize large concentrations of manure. Avoid sites where pollution of natural bodies of water will occur.
Open unpaved feedlot	Lot manure with bedding added.	Tractor scraper to mounds on lot.	Tractor loader to spreader to land.	Mound seldom needs to be removed if it can be maintained firm and dry.
	Wet manure near feed bunks and water.	Tractor scoop to curbed storage slab.	Liquids drain to settling basin, solids loaded to spreader to land.	Storage slab may be upper part of settling basin.
	Runoff from lot and storage slab.	Surface drains to settling basin. Overflow stored in holding pond.	Settling basin sludge: Tractor loader to spreader to land. Holding pond liquid: Pump or gravity flow to land disposal system.	Obtain local SCS advise regarding size of settling basins and holding pond. Apply to land when ground is not frozen and crop will not be damaged.
Open paved feedlot and covered bedded area.	Solid manure in covered bedded area.	Tractor scraper to windrow.	Tractor loader to spreader to land.	Provide sufficient headroom in bedded area for bedding pack plus cattle space (10-12 ft typical).
	Semisolid manure on paved lot.	Tractor scraper to stock pile on curbed slab.	Tractor loader to spreader to land.	Let snow and ice mixed with manure melt and drain before handling.
	Runoff from lot and stockpile.	Surface drains and/or underground pipelines to holding pond.	Pump or gravity flow to land disposal system.	Apply to land when ground is not frozen and crop will not be damaged.
Confined feeding with solid floor.	Semisolid manure at feeding-watering area.	Tractor scraper to stockpile on outdoor curbed or walled slab.	Tractor loader to spreader to land.	Use box spreader with endgate or open-top flail-type tanker.
	Runoff from stockpile.	Surface drains and/or sewer to holding pond.	Pump or gravity flow to land disposal system.	
Confined feeding with totally slotted floor.	Liquid manure........	Manure through slotted floor to tank storage below.	Pump-agitator to tanker to land or added water to storage facility to land.	When agitating liquid manure, remove livestock and open all doors to avoid gas hazard.

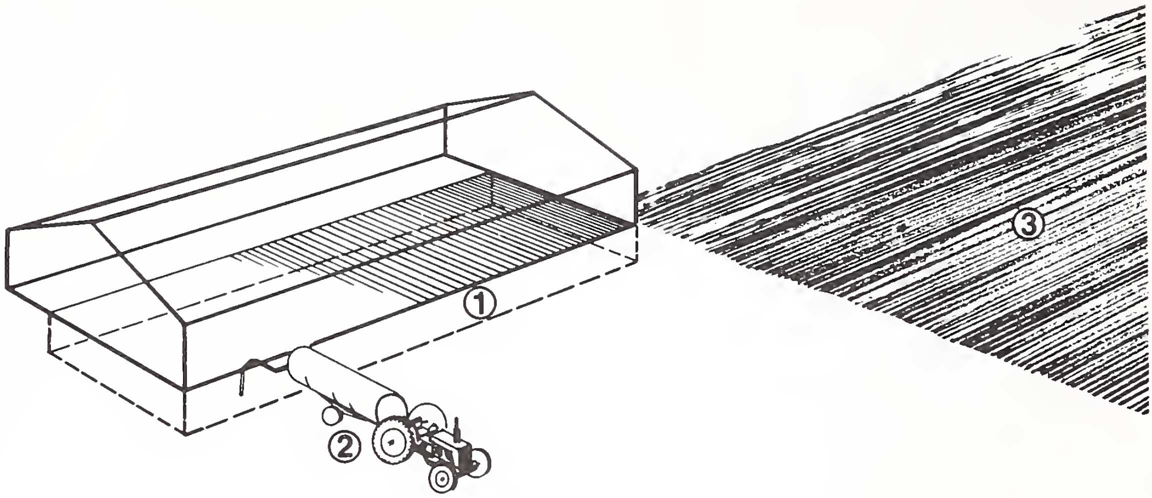

Figure 9-1.--Hauling system (from Circular 1074, Univ. Ill. Coop. Ext. Serv. Livestock waste management in a quality environment. Mar. 1973).

storage period depends on climate, available labor, topography, kind of soil, and crops grown in the utilization area.

2. Pumping and hauling. A pump or vacuum system is used to remove wastes from the collection tank. A liquid-manure wagon is needed to transport the wastes to a utilization area. The wastes can be spread on the surface of the land, but direct injection into the soil reduces odor and the chances of polluting surface runoff.
3. Utilization. Enough land must be available to utilize nutrients in the wastes. The wastes should be applied at times and at rates that will not cause runoff, excessive odor, or damage to crops.

LAGOONS

A lagoon may be used as the basic disposal facility for some livestock production operations. The decision to use lagoons is based on size of the livestock operation, climate, and location and terrain of the available land.

A mechanically aerated lagoon can be designed for any size of livestock operation that has a favorable combination of these factors. Major components of a lagoon system are illustrated in figure 9-2 and described below.

1. Collection. Wastes can be collected in a tank or gutter or scraped to central areas until there are enough to provide flowage to the lagoon. Additional water may be added to provide liquid consistency for pumping and maintaining lagoon operating level.

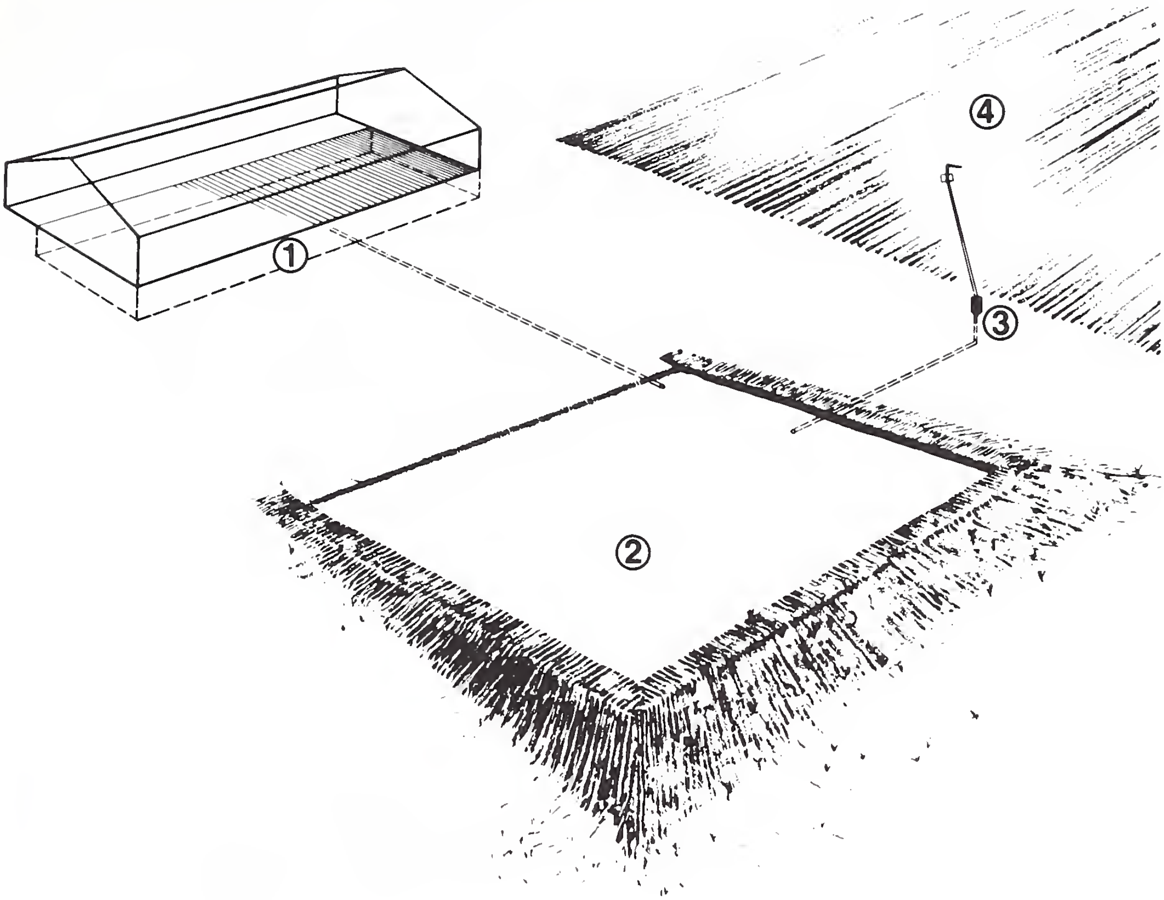

Figure 9-2.--Lagoon system (ibid.).

2. Lagooning. An anaerobic lagoon can be used if some odor can be tolerated. An aerobic, mechanically aerated lagoon can be used if odor control is important.
3. Protection against lagoon overflow. Lagoons must not overflow. Enough freeboard should be provided to take care of some storm water. The liquid level in the lagoon must be maintained through use of a pump and pipeline or other controlled means of disposal.
4. Utilization. Land must be available on which to apply excess lagoon liquids at times and at rates that do not cause runoff, excessive odor, or damage to crops.

GUTTER SYSTEMS

Flushing in Confinement Building

Flushing is a method by which manure is flushed from a confinement building to a lagoon or tank. This system has been used in swine housing and dairy barns. In some free-stall dairy operations, wastes collected

in alleys can be flushed with water collected from cow washing. Figure 9-3 illustrates a flushing system. Major components are described below.

1. Collection. Wastes are deposited in gutters or alleys sloped for drainage.
2. Flushing. A storage tank is filled with water and periodically emptied into the gutters to flush waste from the building.
3. Storage and treatment. Wastes go to an anaerobic, aerobic, or aerated lagoon, or to a holding tank or pond from which they can be pumped to land.
4. Water reuse. Water from the lagoon can be used to refill the flushing tanks if there is not enough fresh water. Recycling some water for flushing the gutters or alleys in the building reduces lagoon overflow and supplements the fresh water supply.
5. Removal of excess liquid. A pump, pipeline, and spray equipment or a tank wagon can be used to remove excess liquid. A pump, pipeline, and spray nozzle are generally more suitable for removing large quantities.
6. Utilization. Land must be set aside for the application of excess waste water at times and at rates that do not cause runoff, excessive odor, or damage to crops.

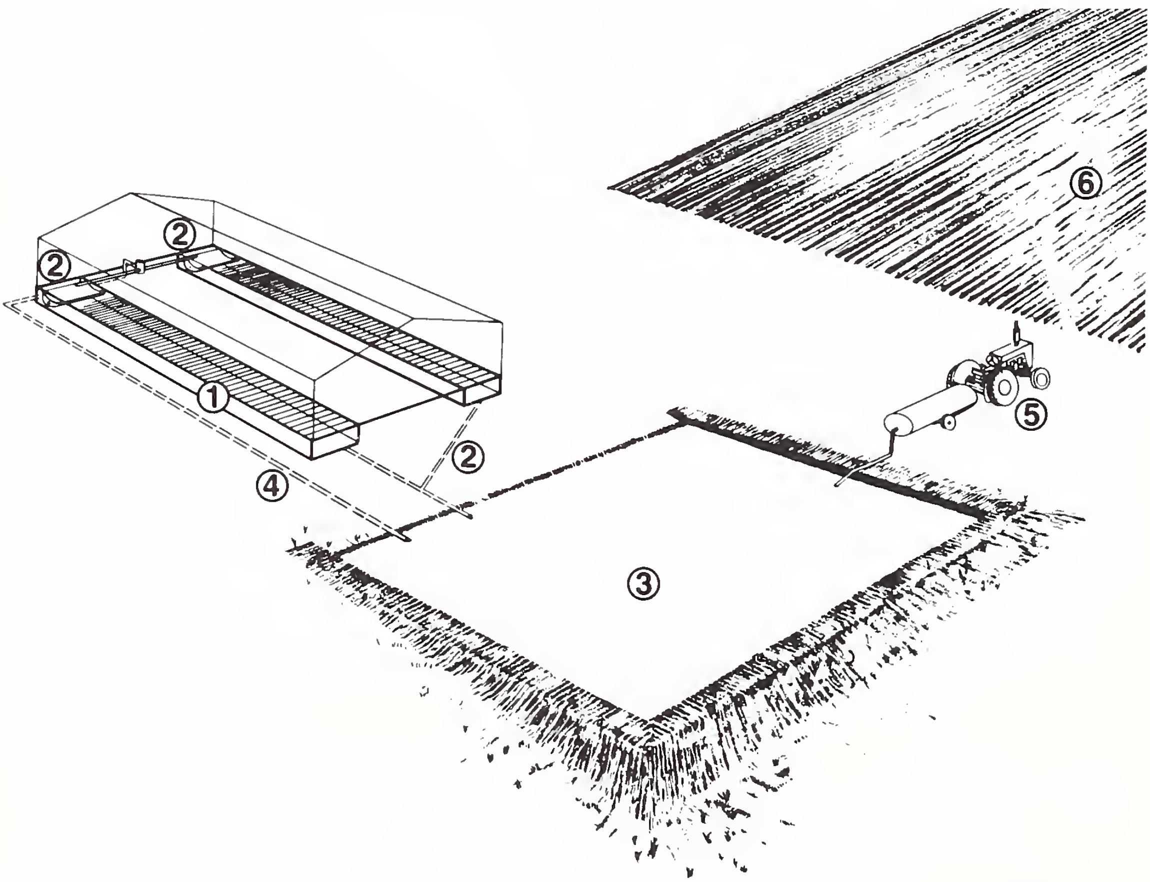

Figure 9-3.--Flushing system (ibid.).

Mechanical Cable Cleaner in Confined Feeding

Wastes are deposited in gutters or alleys sloped for drainage. A mechanical scraper similar to that shown in figure 15-6 of chapter 15 scrapes the wastes either to a storage facility or to a sump from which it is pumped to storage. Stored wastes are applied periodically to a land disposal area by pumps or tank wagons.

Solid Manure and Lot Drainage

Figure 9-4 shows a method for temporary storage of feedlot scrapings and for directing runoff through a settling basin to a storage facility for ultimate disposal on the land.

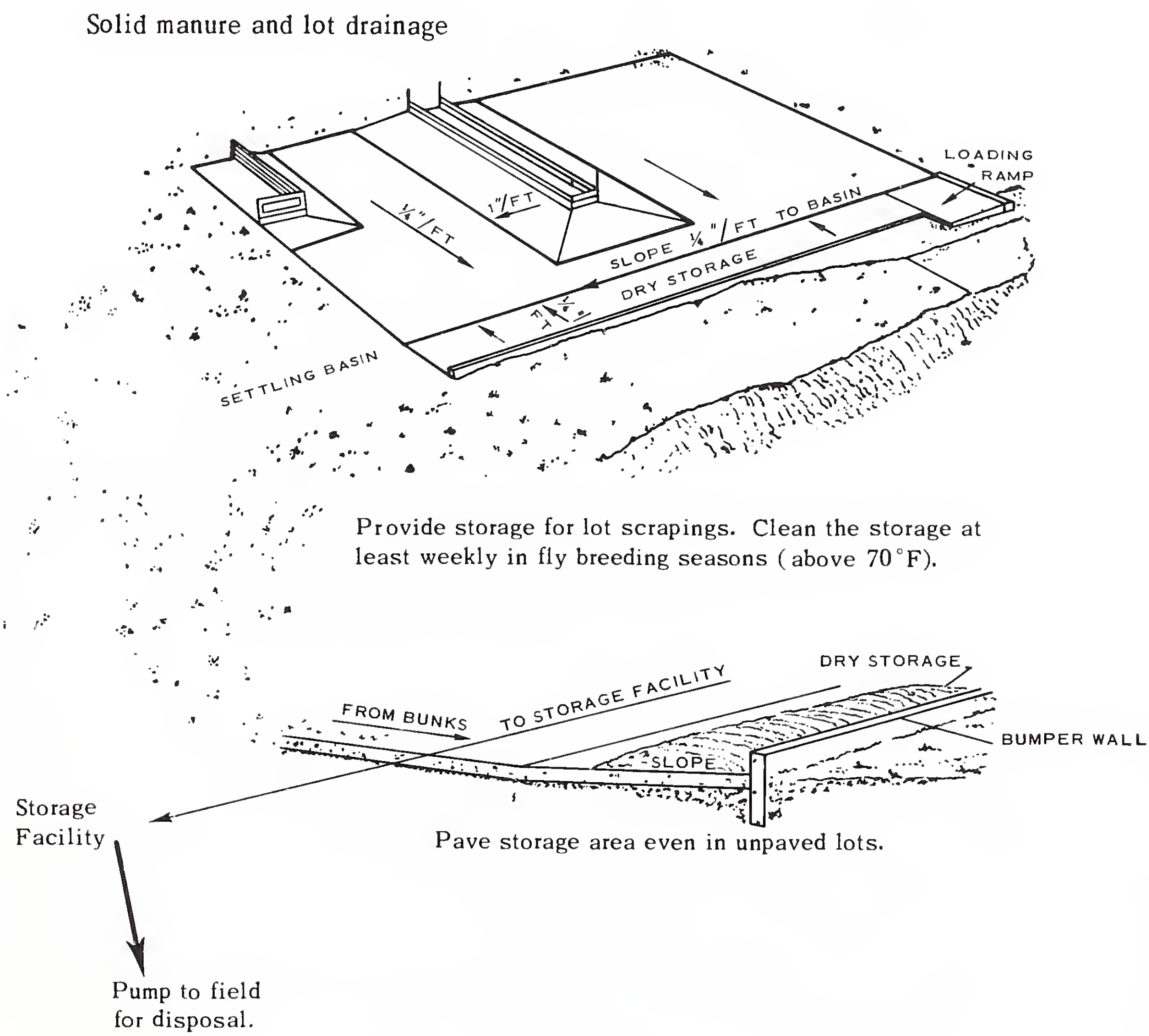

Figure 9-4.--Solid manure storage and lot drainage system.

7. FEEDLOT RUNOFF CONTROL

UNRESTRICTED SPACE

This method is used when feedlot runoff is a potential pollution hazard and there is enough land available for gravity flow of runoff to a holding pond. Figure 9-5 illustrates feedlot runoff control if space is unrestricted. Major components are described below.

1. Feedlot. Most of the solid wastes accumulated on feedlots and in open shelter are handled with conventional equipment and applied to the utilization area. Runoff from the lot, however, carries some solid and liquid wastes that must be intercepted.
2. Clean water diversions. Runoff carrying wastes can be reduced by diverting clean water away from areas where wastes are deposited or stored. Diversions may be needed above and adjacent to the feedlot. Buildings should be guttered. The size of a feedlot can be reduced to the minimum recommended area needed for good animal growth and management.
3. Runoff collection. The runoff from the feedlot must be collected and directed to a central storage area. This can be accomplished through the natural slope of the feedlot or by diversions, gutters, curbing, or pipes.
4. Settling basin. A settling basin slows the velocity of runoff so that some of the solids settle from the runoff water. Solids should not be scraped into the basin. The basin should be shaped to permit cleanout with available equipment. If a tractor loader is used, the bottom of the basin may need to be paved for easy operation.
5. Holding pond. A holding pond receives the liquid from the settling basin. This pond must be large enough to store the runoff for the required storage period.
6. Waste water transport. A system must be included to transport the stored runoff to its utilization area.
7. Utilization. Liquids should be applied to the utilization area at times and at rates that do not cause runoff, excessive odor, or damage to crops.

RESTRICTED SPACE

Many feedlots are boxed in by buildings, roads, lanes, or waterways so that runoff water must be pumped to another area or the livestock must be relocated. Figure 9-6 illustrates runoff control if space is restricted. Major components are described below:

1. Feedlot. See UNRESTRICTED SPACE.
2. Clean water diversions. See UNRESTRICTED SPACE.
3. Runoff collection. See UNRESTRICTED SPACE.
4. Settling basin. See UNRESTRICTED SPACE.
5. Sump pit. A sump pit at the end of the settling basin collects runoff water, which in turn is pumped to a holding pond located

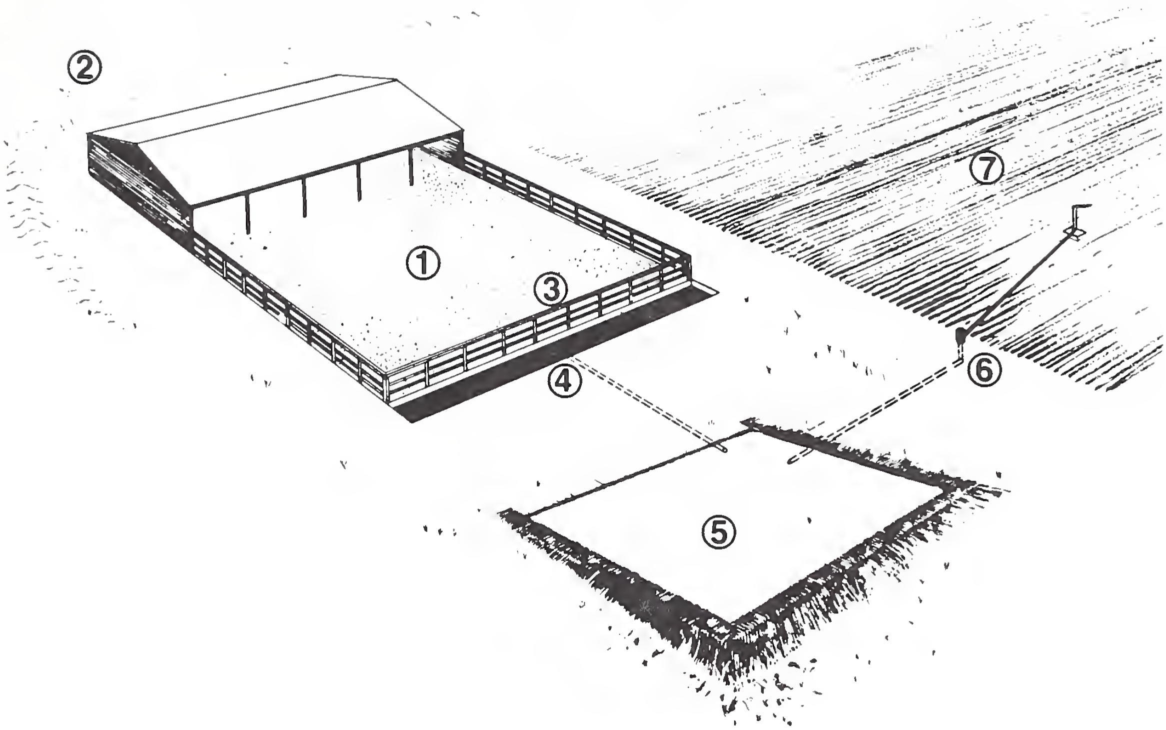

Figure 9-5.--Runoff control if space is unrestricted (ibid.).

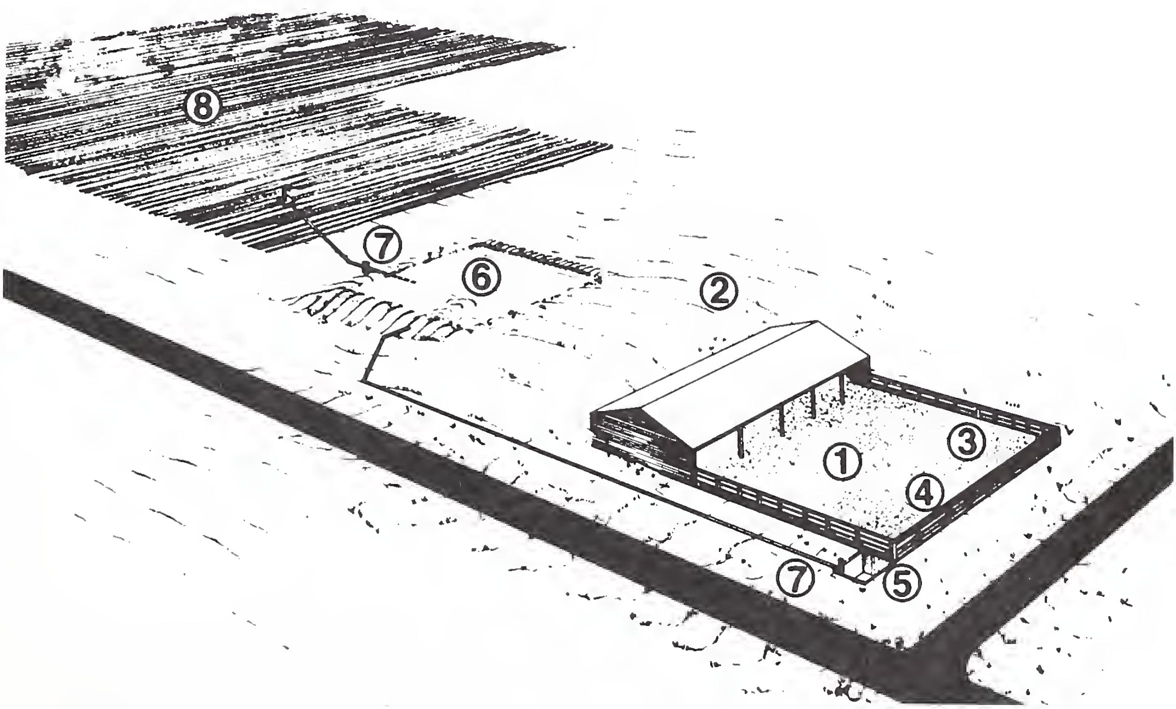

Figure 9-6.--Runoff control if space is restricted (ibid.).

wherever space is available. The sump and pump should be sized to collect and pump water away about as fast as it runs off in the most intense storm.

6. Holding pond. See UNRESTRICTED SPACE.
7. Wastewater transport. See UNRESTRICTED SPACE.
8. Utilization. See UNRESTRICTED SPACE.

PART II - DAIRY CATTLE

1. INTRODUCTION

Management of wastes from dairy farms includes proper handling of livestock manure, control of runoff, and proper disposal of milking center wastes. Control of runoff from feedlots is covered under the Part I subsection entitled "Feedlots." This part of chapter 9 discusses the handling of dairy manure and milking center wastes.

The management of dairy livestock wastes is different from management of other livestock wastes because of the (1) high standards of sanitation required, (2) greater volume of manure per animal, and (3) large amount of manure deposited within buildings. Accumulations of manure in the feedlot or exercise yard must not be permitted. Fly and fly larvae must be controlled in adjacent areas even if livestock are excluded from those areas.

Many dairies are located in areas of relatively high population density. This compounds the problem of manure disposal. Air and water pollution must be considered, and waste management facilities should not be offensive to the surrounding neighborhoods.

2. MANAGEMENT OF DAIRY ANIMAL WASTES

GENERAL

Whether dairy animals are confined within a building continuously or only part of the day, management of the wastes must provide for handling all liquids and solids. If the dairy installation includes a hard-surface lot, periodic scraping and proper disposal or storage of the accumulated wastes are necessary. Some method of storage usually is needed. One storage area for wastes from both outdoor lots and inside buildings can be used.

The most common types of dairy facilities are free stall, stanchion, or loose housing. A brief summary of each of these follows.

Free Stall

This method of housing provides stalls that the cattle may enter or leave at any time. They are never confined in one place. Little bedding is used. The stalls are made to an exact size and normally raised from the aisle floors to allow manure to drop onto the aisle floors rather than in the stalls. The cows can walk into the stalls, lie down, and

back out again, thus keeping the stalls clean. Feeding is usually done in one area of the building. Milking is usually done in an adjoining room or building.

The aisle floors can be scraped by automatic equipment, by small loaders, or even by hand if adequate labor is available. Many free-stall arrangements have liquid manure tanks beneath the barn. Slotted floors allow the manure to drop directly into the tank. In other arrangements, openings or large slots are at strategic locations around the top of the tank into which wastes are scraped periodically. Since little bedding is used and the manure is liquid, any outside storage facilities must close on all sides. Outside storage facilities for liquid manure should have the same approximate strength needed for other liquids. The manure can be loaded into the outside facilities by mechanical cleaners, manure stackers, front-end loaders, pumps, or by flushing. Pumps are popular in some areas. A pump should be located below floor level so that wastes can be pushed into the pump hopper. They can then be pumped through underground pipes into an outside storage facility.

Stanchion

Stanchion barns also consist of stalls. The cattle, however, are confined during certain periods of the day. Manure is deposited into a gutter located immediately behind the cattle. Barn cleaners work well for cleaning the gutters. Manure stackers then take the manure from the barn cleaner and pile it into stacks outside the building. This type of housing uses some bedding; thus, the manure is more easily contained in outside above-ground storage facilities than is the waste from free-stall housing. Because of bedding, pumps are not well suited to moving the manure to outside storage.

Loose Housing

Loose housing consists of an open building that protects cattle from the weather but does not confine them within the building. Manure is allowed to accumulate, and additional bedding is placed on top of the existing pack. Considerable bedding is required to maintain the necessary cleanliness. Of the three systems described, this is the least popular in northern climates.

PLANNING A DAIRY WASTE MANAGEMENT SYSTEM

The kind of waste handling system a dairyman should have, including type of facilities, their capacity and design, and management practices, depends basically on the number of animals he has and his operation preferences. The following must always be considered, however, for development of a complete system: (1) present and future herd size, (2) site topography, (3) soils, (4) land available and crops grown or other land use on the area reserved for waste disposal, (5) climate, (6) environment, (7) planned management and available labor, (8) available equipment, (9) sanitation requirements, and (10) state and local regulations. Failure to consider any of these items may result in waste management

that is only partly effective. Waste facilities for dairy farms are costly, and it is important to provide the best system initially so as to avoid the need for future modifications.

Present and Future Herd Size

Waste management systems at the beginning must take into account possible expansion, since there is a continuing trend for dairy herds to enlarge.

Plans for waste disposal should include also the separate facilities necessary for young stock or heifers on the farm. The method of bedding and manure handling for young stock may be quite different from that for milking cattle.

An estimate of the amount of manure produced per cow per day is required for proper management. Chapter 4 contains data on the range of manure production reported for dairy cattle. Table 9-2 indicates the amount of solid and liquid manure to expect from dairy cattle of various sizes. Some bedding is usually required in any dairy plant. Table 9-3 provides estimates of the weight of bedding needed. Table 9-4 can be used to estimate the volume of bedding required for cattle.

Table 9-2.--Dairy cattle manure production

Weight of cattle	Feces and urine
lb	ft^3/day
1,000	1.3 to 1.6
1,200	1.4 to 1.9
1,400	1.6 to 2.2
1,600	1.8 to 2.5

Table 9-3.--Bedding requirements for dairy cattle

Housing system	Bedding
	lb/cow/day
Stanchion barn	4 to 8
Free-stall housing	2 to 5
Loose-housing bedded area	Up to 20

Site Topography

Topography has considerable bearing on the type of waste facilities that can be constructed. It may also have considerable effect on the total cost involved. Slope must be great enough for proper runoff control. If the natural slope is not enough for necessary drainage, either excavating and regrading or hard-surfacing the lot is necessary. Lots should have an average grade of 2 to 6 percent if hard surfacing is not provided. If the lot is hard surfaced, the grade may be less than 1 percent and the

Table 9-4.--Density of bedding material

Material	Density
	lb/ft^3
Straw:	
Loose	3.5 to 4.5
Baled	6.0 to 10.0
Chopped	5.7 to 8.0
Shavings:	
Baled	$20\pm$
Loose	8.8
Sawdust	12

lot still have proper drainage, assuming the wastes are periodically removed as they accumulate. Periodic removal is usually necessary for the required cleanliness.

Outside lots or yards are normally small. The amount of runoff that drains from building roofs, therefore, may be considerable when compared with that for the total area. Eave troughs on the buildings in the lot area should be considered. As in all installations, the clean water should be diverted around the lot or yard area.

Topography also affects the type of storage facilities to be provided. There must be adequate room for solid-manure storage facilities. The slope of the land may considerably affect construction costs of any underground storage facilities. Liquid-manure tanks should not be exposed to freezing temperatures. In northern climates considerable fill may be needed as protection to sidewalls if the slope is relatively steep.

The location of the barnyard with respect to disposal areas and fields also affects the method of transporting the wastes. Gravity systems for handling waste-water runoff are desirable from a cost standpoint. Pumps are an expensive item and may require considerable maintenance over a period of years.

Soils

Soils and soil conditions must be considered for proper control of pollution. Disposal of wastes on soils that have a high permeability rate, such as gravel, may lead to ground-water pollution. Waste disposal or storage should not be attempted on areas of rock outcrop before the fractures are sufficiently sealed. Ground-water depth may influence the type of facilities on a particular site. For example, liquid-manure tanks in areas with a high water table must be specially designed. Frozen ground, snow, or excess moisture at certain times of the year may make it necessary to retain polluted runoff in holding ponds until soil conditions are suitable for disposal on land.

Land Availability and Use

Daily spreading of manure is often necessary to control flies during the fly season, and sufficient area must be available for this. Land availability also affects the volume of storage required. For example, if most of the land has been sown to crops and the only remaining land is in hay, storing manure may be better than spreading it on hay or pasture at a time when quality of the forage would be adversely affected. Crops utilize more of the nutrients in livestock manure during certain periods of growth. Thus, in his plan for spreading manure on land, the dairyman must consider both the amount of land available and the periods when it can be used for spreading.

Climate

Climate has a bearing on the size of needed waste management facilities. Storage facilities must be large enough to store manure when inclement weather delays their emptying. In many northern climates this may be as long as 180 days. Spreading livestock wastes on frozen ground can create a pollution hazard, especially if the ground has appreciable slope towards lakes, streams, or rivers. Holding ponds for runoff from lots generally should not be emptied during the winter months. In some areas manure disposal is delayed because of the depth of snow cover. Wastes should not be disposed if there is danger of excessive runoff that may pollute other water. Maximum use of conservation measures for reducing runoff should be made when spreading is necessary on frozen ground or on land with steep slopes. Such measures include contouring, contour stripcropping, terraces, mulch tillage, and other agronomic practices.

Environment

The area surrounding the dairy plant influences the method of waste disposal. Since many dairy farms are located near urban areas, the wastes must be handled in a manner that holds odor to a minimum. Liquid-manure tanks, although not offensive in the storage period, can be odorous at the time of emptying. Favorable wind direction or immediate plowing of wastes beneath the surface reduces the odor.

Also, the dairy industry is concerned about the overall appearance of dairy farms since the appearance of production facilities influences public acceptance of food, especially milk.

Various methods for screening livestock waste facilities from public view are suitable. Earth fills, seeded and landscaped, have been used extensively. Trees contribute greatly to good overall appearance. In northern climates, trees properly located also can help keep drifting snow out of the waste storage facility and feedlots.

Management and Available Labor

In any dairy enterprise, the extent to which the waste management system can be automated is important. Little management or labor is required during the period in which a liquid-manure tank is filling. The

way the tank is emptied determines the labor required to spread the manure on land. A mixture of sufficient liquid with solids can be successfully pumped through pipe and spread directly on the land by spray application, requiring perhaps the least amount of labor. Pumping liquid manure from the storage tank into tank wagons and then hauling it to the field requires considerably more labor, which must be available to spread the manure and, if possible, to work it into the soil before a crop is planted.

If stacking procedures are used, little labor is required during parts of the year. These procedures differ from others mainly in the type of equipment used for loading the wastes onto spreaders and hauling to the field. Solid manure stacks can be loaded by conventional equipment such as front-end loaders, which are usually available. Liquid manure, however, requires more specialized equipment, which offsets some of the advantage of reduced labor.

Available Equipment

Various kinds of equipment are used for handling manure. Much of it is specialized and not readily available on many dairy farms. Consequently, either such equipment must be purchased or an alternative design must be prepared to allow the use of more conventional equipment. Liquid manure requires pumps or some other special equipment. Solid manure requires stackers. However, standard equipment such as conventional front-end loaders can be adapted for removing animal wastes from yards to stacking areas.

In some instances other methods of handling manure may be better for a given dairy operation. Earth storage facilities are common for combined liquid and solid wastes from free-stall systems. These ponds are usually emptied by pumps. It is easy, however, to construct hard-surfaced ramps into the ponds so that front-end loaders can be used. Front-end loaders are especially useful after the liquid in the pond has been removed by pumping.

Systems using a stacker and a tank and a storage pond using a pump are shown in figures 9-7, 9-8, and 9-9.

Sanitation

Sanitation must be considered in overall planning for all waste management systems on dairy farms. Approval or concurrence of all agencies concerned must be obtained before construction is begun. Health or milk inspectors should be consulted. Many state regulatory agencies have requirements that must be met.

Proper fly control must be maintained at all times. Control of fly larvae is more difficult when fresh manure is allowed to accumulate. However, manure left undisturbed for periods of time without any additions of fresh manure is not so attractive to flies.

Locating manure storage facilities as far as possible from the milkroom helps alleviate the fly control problem. Daily hauling and disposal of manure during the fly season also helps. Fly breeding sites

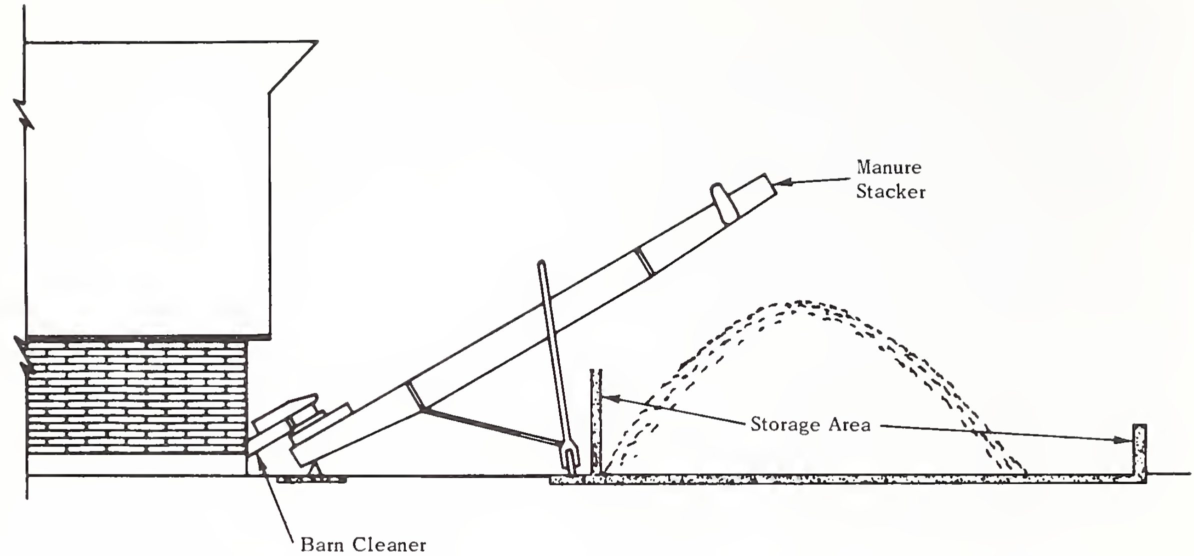

Figure 9-7.--Typical storage system using manure stacker. Manure with bedding will form stack as indicated. Manure from free stall will slump to nearly level conditions. Walls of storage area to be designed in accordance with standards. Size of area is dependent on management, climate, size of herd.

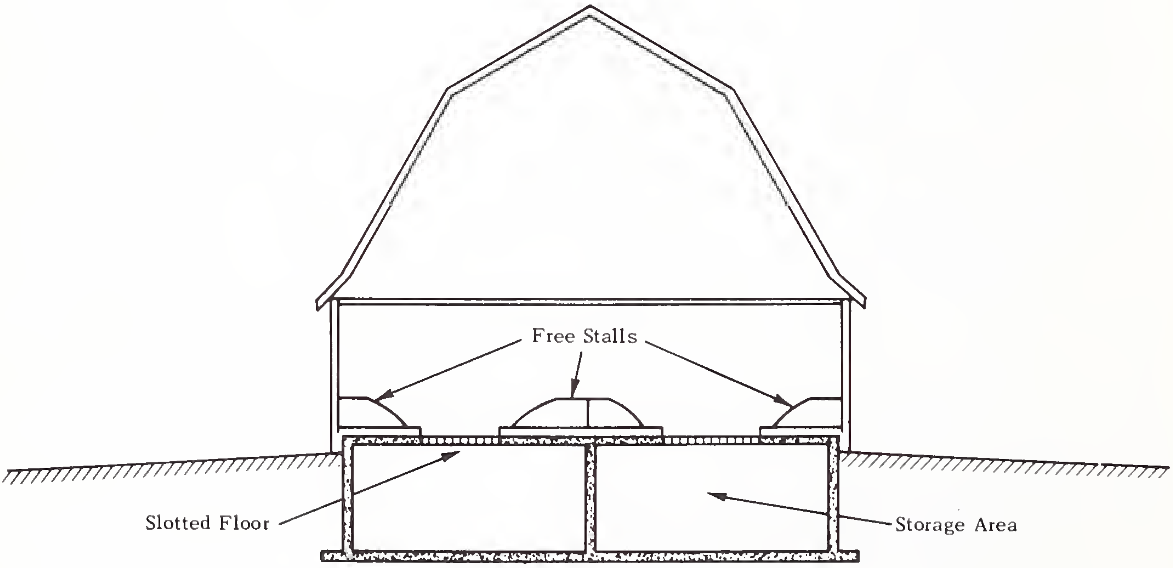

Figure 9-8.--Manure storage system using liquid-manure tank. Openings in floor into which manure is scraped may be used in lieu of slotted floor. Tank may be located beside building; manure is then scraped into openings. Manure must not be allowed to freeze. Large tanks should be divided into compartments to facilitate agitation. Sufficient openings for cleaning and ventilation are necessary.

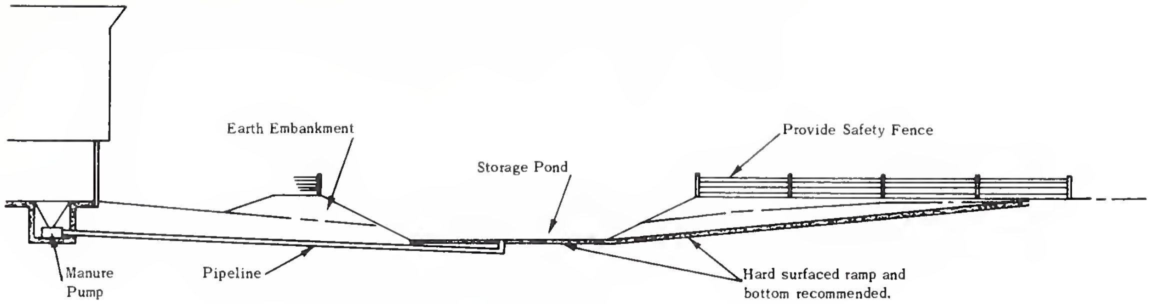

Figure 9-9.--Manure storage pond using manure pump for loading. Capacity should be based on level full condition. Pumping station may facilitate cleanout. Pipe should outlet into or near bottom of pond. Pond should be lower than pump to prevent backflow.

include rotting feed and straw, calf pens, gutters, feed bunks, and unpaved portions of lots with poor drainage.

Animal waste facilities must also be located at a safe distance from water wells. Many local and state regulations specify the minimum distance required.

3. MILKING CENTER WASTES

MANAGEMENT OF MILKING CENTER WASTES

A considerable amount of waste originates in the milking centers of dairy farms. The four main areas are the toilet, milkhouse or milkroom, milking parlor, and holding area.

Human wastes from washrooms and toilets in dairy facilities should never be mixed with animal wastes and placed in liquid-manure tanks or other agricultural waste storage facilities. They should be handled in the same way as domestic household sewage.

COMPOSITION OF MILKHOUSE AND MILKING PARLOR WASTES

Waste water from milkhouses includes varying amounts of milk, detergents, cleaners, and sanitizers. Wastes from the milking parlors include dilute disinfectant, manure, and waste feed.

Milk is a strong waste product and can quickly pollute a stream. Materials contained in the solids of milk include fat (2.5 to 8 percent); casein (2.3 to 4 percent); albumin (less than 1 percent); lactose (approximately 5 percent); and ash (approximately 0.5 percent). These are expressed as percentages of the total weight of whole milk.

The fats and proteins in the milk present the greatest disposal problem. These substances do not decompose in anaerobic disposal systems and cannot be removed in settling basins.

Disposal of milk from fresh cows or treated cows should have special consideration. If this milk is not used for feeding swine or other young stock, it should be spread on the land or placed in a liquid-manure tank. The milk should never be put into a subsurface disposal system nor placed where it can enter a stream.

AMOUNT OF LIQUID WASTES PRODUCED IN MILKHOUSES

The volume of liquid wastes produced in a milking center varies greatly. The variation is caused by type of milking system, equipment, size and number of milk tanks, and the general procedures followed by the dairyman. Table 9-5 gives estimates of the volume of wastes that may be produced from an average size operation of 50 to 100 head.

Table 9-5.--Milkhouse wastes

Equipment	Water used per washing
	Gallons
Bucket milkers	35-50
Pipeline	80-180
Bulk tank	20-40
Milkhouse floor	10-20

AMOUNT OF LIQUID WASTES PRODUCED IN MILKING PARLORS

Additional water is required for washing if milking parlors or special milking rooms are used. The amount of additional water varies, depending on such factors as number of cows, type of milking setup, size of parlor, method used to wash cows, and individual procedures. If a hose for washing cattle is allowed to run water continuously, the amount of water used is as much as 7 gal per day per cow. If the water is not used unnecessarily, only 3 to 4 gal per day per cow may be needed.

A milking parlor with three to eight stalls requires 40 to 100 gal per day for washing or hosing down, depending in part on the amount of waste feed to be washed away.

DISPOSAL OF WASTES FROM MILKING CENTERS

Lagoons, liquid-manure tanks, and holding ponds or other waste storage facilities are used for the disposal of wastes from milking centers.

Lagoons

Lagoons are commonly used for handling milking center wastes. Settling tanks or basins that can be cleaned periodically are often used to retain solids that settle out from the liquids. These settling structures can be incorporated into the system at any place between the milkhouse and the lagoon. Lagoons should be aerobic for decomposition of the fats and proteins contained in milk solids.

The surface area of the lagoon can range from 50 ft^2 to 125 ft^2 per cow. The actual area depends on the amount of solids entering the lagoon, the climate, and other local factors.

The depth of naturally aerated lagoons should be maintained at 2 to 5 ft. Odor will be held to a minimum if the proper depth is maintained. Depths greater than 5 ft prevent maintenance of aerobic conditions and result in unsatisfactory lagoon operation.

Liquid-Manure Tanks

The liquid-manure tanks used for holding cattle manure can also be used for wastes from milking centers since waste milk and feed, which become a problem for other types of disposal, do not restrict the effectiveness of these tanks.

If liquid wastes are to be drained into liquid-manure tanks, additional storage is required. Floor levels should also be carefully planned to allow for maximum use of the tank capacity.

Placing the wastes from the milking center into liquid-manure tanks facilitates removal of the manure when the tank is emptied because the additional liquid reduces the percentage of solids in the wastes, facilitates agitation, and allows easier pumping directly from the tank to spray nozzles in the disposal field.

Holding Ponds

A holding pond can store milking center wastes temporarily. If the pond is not sealed, the soils should be relatively impermeable so as not to risk ground-water pollution. A settling basin can be used to remove solids such as waste feed before the liquid wastes reach the pond.

A holding pond should be pumped periodically and the contents spread on the land. Sprinkler systems are well suited for disposal of the liquids. The pond should be large enough to hold the liquids between periods of emptying, provide emergency storage, and also hold any solids that may accumulate. Solids accumulation can be quite significant if there is no settling basin.

Pond locations that are pleasing to see should be chosen. Emptying the ponds frequently will keep odor to a minimum.

Reuse of Wash Water

The total amount of water required in a milking center can be reduced by recycling. Wash water in a milking system can be reused for washing and cleaning the milking parlor. However, a separate collection tank and a pump are needed for this, and the collection tank also requires periodic cleaning.

PART III - SWINE

1. GENERAL

The production of swine ranges from feeding small groups of hogs on pasture to growing several thousand in modern, automated confined housing. The types of waste management facilities needed depend on the type and size of the swine operation.

The planning and installation of waste management facilities must be based on an entire systems approach rather than on installation of individual parts. Planning must include analysis of the landowner's

long-range objectives and a study of available land, labor, capital, and management resources.

Major phases of swine production are farrowing, nursery, and finishing. Most producers have a combination of buildings for these various operations and often use a combination of manure-handling facilities for a satisfactory system. For all systems except those using pasture, consideration must be given to facilities for the collection, storage, transportation, and utilization of all solid and liquid wastes. Systems must be so planned to provide efficient ways to manage the waste produced and minimize water pollution. Most systems provide for returning the wastes to agricultural land. Return of wastes is the most suitable method of disposal, and it accomplishes effective recycling. Pollution of surface and ground waters is eliminated if wastes are spread properly. Major waste management systems commonly used for swine production are described and illustrated in the following pages and also in figure 9-10.

2. PASTURE SYSTEMS

Hogs can be raised on pasture but without good management this may result in extensive problems with animal health and pollution control.

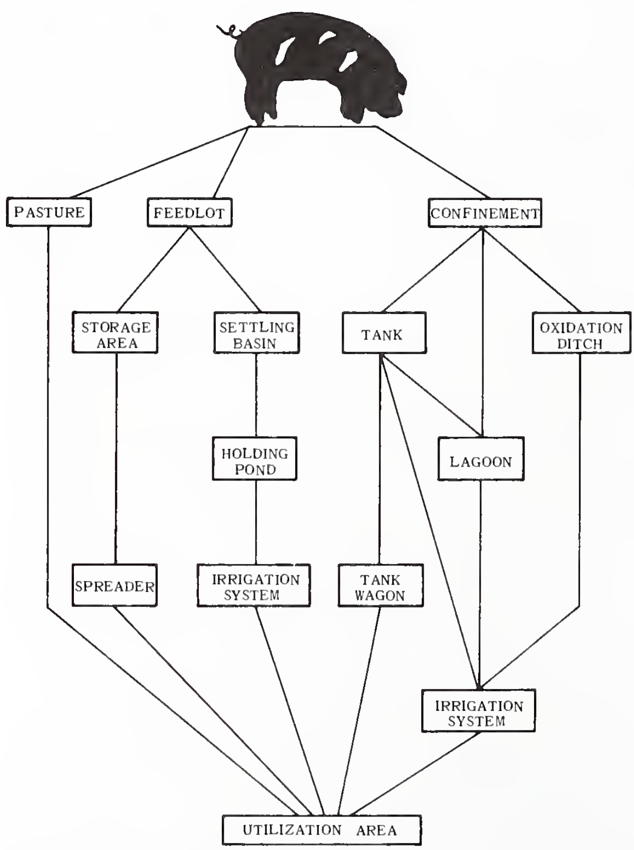

Figure 9-10.--Common waste management systems.

If the pastures are well located and large enough for each animal to have adequate room, waste is not so concentrated. If the animals are crowded and the lots are devoid of vegetation, there is danger of runoff pollution.

It is difficult to treat runoff problems in most pasture production operations because of the large area involved and the often difficult topography for collection of runoff. Many producers change to more concentrated forms of production rather than invest in runoff control or waste management facilities for pastures in which there is a problem of polluted runoff.

Raising swine on pasture is less efficient than more concentrated operations, but the low initial investment makes it a very popular system of production. Needed facilities should be planned in accordance with the guidelines for feedlot systems.

3. FEEDLOT SYSTEMS

Many swine enterprises use feedlots or partially sheltered feedlots for swine finishing. The form of the wastes from such feedlots determines the most satisfactory waste disposal method.

SOLIDS HANDLING SYSTEM (PARTIAL CONFINEMENT) WITH NO CONTAMINATED RUNOFF

Partially sheltered feedlots are still widely used for swine production. They are particularly common in older facilities being modified to include complete management systems. If swine manure is handled as a solid, bedding is normally required to permit handling the waste with conventional equipment. Reducing the size of the feedlot, cleaning the feedlot frequently, and reducing runoff by evaporation and diversion minimize runoff pollution. Placing feedlots on suitable soils at adequate distance from streams also lessens the risk of water pollution.

Storage for solids may be necessary if weather conditions prevent frequent removal of waste to utilization areas. Each storage area must be designed with consideration given to soils, adjacent facilities, available equipment, and length of storage period.

This type of feedlot system requires a minimum capital investment and permits the use of conventional waste-handling equipment. It is usually limited, however, to small production enterprises on suitable sites away from streams.

SOLIDS HANDLING SYSTEM WITH RUNOFF CONTROL

This system is suited to all operations where runoff from feedlots may cause pollution. Major components of a typical system, similar to those illustrated in figure 9-5, are described as follows.

1. Feedlot. Wastes accumulate on the feedlot and in the shelter area and, as conditions permit, are loaded into conventional manure spreaders and transported to the utilization area.

2. Diversions. Diversions and roof gutters lessen the amount of clean water that has access to the feedlot and other sources of contamination. Feedlot size may also be reduced to the minimum recommended area required for good animal growth and management.
3. Runoff collection. Gutters, curbs, and other collection facilities in the feedlot or around the perimeter direct the runoff to a settling basin.
4. Settling basin. A settling basin receives the contaminated runoff. It should be large enough for settling and storage of the accumulated solids until they can be transported to the utilization area. A settling basin may consist of a diversion, a low gradient channel, or a constructed basin with appropriate outlet structures. Settling basins with a concrete bottom make removal of the waste easier.
5. Holding pond. A holding pond receives the liquids from the settling basin. If there is insufficient room for gravity flow between a settling basin and holding pond, it may be necessary to install pumps near the feedlot at the settling basin to transport runoff to the holding pond at another location. The holding pond must be large enough to store runoff during periods when disposal on agricultural land is not feasible. The holding pond must be emptied in accordance with an overall waste management plan to insure available storage capacity for subsequent runoff. A holding pond should be fenced and vegetated for safety and good appearance.
6. Waste-water transport. If inflow into the holding pond exceeds evaporation and permissible seepage, a sprinkler system may be needed to discharge stored waste water to the utilization area.
7. Utilization area. Liquids should be applied to the utilization area at times and at rates that do not cause runoff, excessive odor, or damage to crops.

A solids handling system with runoff control has the advantage of providing positive control of contaminated liquids from the feedlot. It also provides for using conventional equipment to handle most of the animal waste. The principal disadvantages are the additional investment and the need for specialized equipment to manage runoff control facilities.

4. CONFINEMENT SYSTEMS

In most new swine production facilities, animal production is entirely within a shelter. The advantages are management efficiency, optimum use of feed, health control, and effective waste management. These systems represent a high initial investment and require skillful management.

LIQUID-MANURE SYSTEM

The simplest and most common method of waste management in a confinement system is slotted floors over a manure tank beneath all or

part of the building so that wastes are deposited directly into the storage tank. Major components of such a system are similar to those illustrated in figure 9-1.

1. Collection. The liquid-manure tank is placed under part or all of the building or located outside the building. Buildings usually have slotted floors if tanks are under the building. If the tank is under only part of the building, adjacent solid floors may be sloped so that wastes are concentrated in the tank area. If the tank is located outside the building, wastes are scraped into sumps or pits for subsequent removal. Tanks should be large enough to store accumulated manure and wash water for the longest anticipated period between emptyings. The storage period depends on the kind of soil, crops, topography, climate, availability of labor, and state laws and regulations governing the disposal of animal wastes.
2. Tank emptying. A liquid-manure wagon is commonly used to remove wastes from the liquid-manure tank. Vacuum-type wagons can be used for swine wastes. These wastes are spread on the surface of the land or injected into the soil through equipment attached to the liquid-manure wagon. Direct application or incorporation by cultivation of wastes into the soil reduces both odor and surface runoff. Tank contents may be directed to disposal lagoons.
3. Utilization. Enough agricultural land should be available for the application and utilization of the wastes. Wastes should be applied at times and at rates that do not cause runoff, offensive odor, or damage to crops. The soils in the utilization area should be tested to determine the proper application of supplemental fertilizers.

A sprinkler system or other method of surface application can be used to transport wastes directly from the tank to the utilization area, especially if a large volume of water has been added, but the area must be managed to reduce odor and runoff.

Liquid-manure systems have the following advantages:

1. A large part of the fertilizer value in the manure is returned to the land.
2. If storage capacity is adequate, manure can be spread at the owner's convenience.
3. Labor costs are lower because of the concentrated form of the wastes and the efficiency of equipment.
4. Flies and odor can be reduced by proper management.

The disadvantages are:

1. The system has a high initial cost compared to other common methods of waste management.
2. Sufficient land must be available for utilization of the wastes.

LAGOON SYSTEM

Lagoons may be the principal disposal systems for some swine production enterprises. A lagoon must be located so as to control odor and to prevent outside runoff from entering the lagoon. Contamination of ground water must be avoided. Thus soils at the lagoon site should be impervious or suitable for sealing. Major components of systems using lagoons are similar to those illustrated in figure 9-2 and are described as follows:

1. Collection. Wastes can be collected in a tank or gutter or scraped to central areas until there is enough volume to provide flowage to the lagoon. Gutter flushing can be used both to clean the building area and to transport wastes to the lagoon. Use of a liquid-manure tank with ample storage beneath the building and periodic removal of solids deposited in the tank will reduce the volume in the lagoon.
2. Lagoon. Lagoons can be used singly or in combination. They can be aerobic, anaerobic, or facultative. Aerators can be used in anaerobic lagoons to control odor and maintain aerobic conditions on the surface of the lagoon.
3. Overflow control. In most climates lagoon inflow exceeds evaporation. In these areas lagoons must not be permitted to overflow unless the overflow is given enough treatment to meet approval of the state agency having jurisdiction over waste treatment systems. The effluent from manure lagoons is seldom of suitable quality for discharge to surface waters. Enough freeboard should be allowed to provide storage for runoff from contributing areas. The liquid level in the lagoon can be maintained by using a sprinkler system or, in small waste management systems, a liquid-manure wagon.
4. Utilization. Land must be available on which to apply successive lagoon liquids at times and at rates that do not cause runoff, odor, or crop damage.

Lagoons have the advantage of requiring little labor and a relatively low initial investment. They have the disadvantages of requiring fairly large land areas, possibly causing ground-water pollution, occasionally giving off excessive odor, destroying some of the nutrient value of wastes, and in northern areas, freezing.

Aerobic Lagoons

Aerobic lagoons are relatively odor free. They must be shallow, however, and they need a substantially larger surface area than other types of treatment facilities. They may need large amounts of water to maintain the liquid level. Aerobic lagoons function under warm, sunny conditions that favor the growth of algae. For these reasons they are most suitable for small operations in southern areas. They can be used effectively as the last stage in a series of lagoons or as the recipient of wastes already partially treated by oxidation ditches or some other method.

Anaerobic Lagoons

Anaerobic lagoons function at greater depths and with higher concentrations of waste than aerobic lagoons. Odor and potential groundwater contamination are the major limiting factors in the use of anaerobic lagoons.

Lagoons can be mechanically aerated to control odor. Lagoons designed for mechanical aeration should be 12 to 18 ft deep with construction similar to anaerobic lagoons. The additional operating cost for mechanical aeration is significant.

Perhaps the most effective use of an anaerobic lagoon is in a system in which it receives the overflow from a liquid-manure tank. Liquids flow to the lagoon, and the solids remain in the tank. This method allows the operator flexibility in management and eliminates the need for hauling wastes when conditions are not favorable. This method also reduces lagoon loading; thus, the chance for odor is lessened, a smaller lagoon is needed, and the lagoon lasts longer.

The disadvantages of this system are the added expense for installation and the additional equipment needed to manage both the tank and the wagon.

OXIDATION DITCH SYSTEM

An oxidation ditch is a mechanical method of aerobically treating liquid wastes. It has been used effectively in farrowing operations and can be used in all operations where the necessity for odor control is critical. Major system components are illustrated in figure 9-11 and are described in the following pages.

1. Collection. The ditch is a shallow tank shaped like a racetrack so that the contents can be circulated continuously. Waste drops into the ditch through slotted floors.
2. Aeration. An aeration rotor or propeller circulates the liquid waste, adds the air needed to supply oxygen, and keeps all solids in suspension. This equipment must operate continuously.
3. Sludge trap. A sludge trap is generally provided in the overflow line to settle sludge.
4. Ditch overflow. Excess waste water can be routed to a large tank or aerobic (naturally or mechanically aerated) lagoon. The volume of waste water is usually reduced by evaporation at the rotor. Odor can be controlled because the waste water is partially treated.
5. Protection against lagoon overflow. To keep the lagoon from overflowing, some of the excess liquid can be pumped or hauled to a utilization area with a pump and pipeline or a tank wagon.
6. Utilization. The utilization area for excess liquids can be a relatively small area of cropland set aside for the purpose. The waste water should be applied at times and at rates that do not cause runoff, excessive odor, or damage to crops. Oxidation ditches can reduce the volume of wastes handled, odor, and the danger of pollution. Major disadvantages are the high initial cost of construction and equipment, increased operating costs, and the close management necessary to insure proper operation.

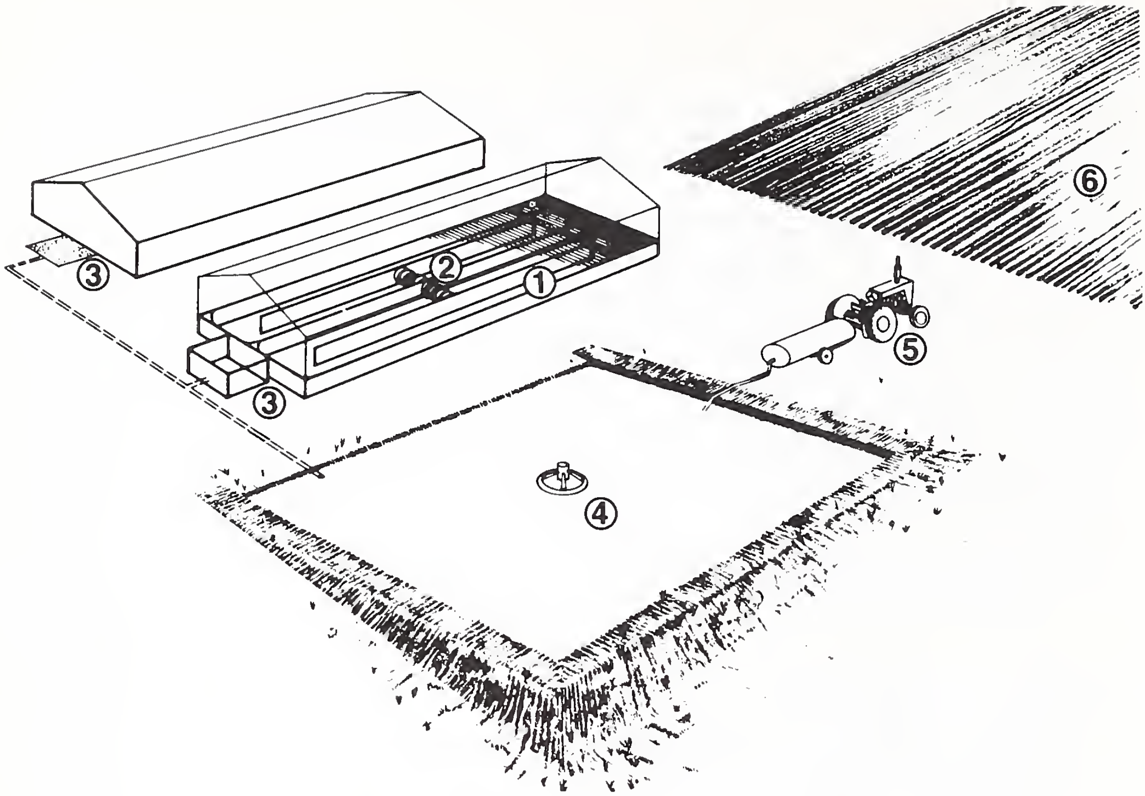

Figure 9-11.--Oxidation ditch system (ibid.).

5. OTHER SYSTEMS

At the present time several additional systems of waste disposal are being evaluated. These systems generally consist of recycling wastes in the liquid form or dehydrating and utilizing the solids. Swine wastes, because of their higher liquid content, are less suited to dehydration, incineration, and composting than other wastes.

Research in recycling swine wastes to swine as feed, after stabilization in oxidation ditches, is currently underway. The high protein content of the ditch liquor would make this an efficient system.

PART IV - POULTRY

1. GENERAL

This section provides current information on the most practical methods for management of poultry wastes. Systems for producing a marketable byproduct, such as incineration, recycling as feed, and composting, are not included.

2. CHICKENS

LAYING HENS

Since the trend is toward increasingly larger commercial complexes, methods of waste disposal for small-scale enterprises are not considered. The major egg producers often have complexes providing confinement housing for 15,000 to 30,000 birds. Some have 300,000 to 500,000 birds, and a few operate at a level of a million birds or more.

Dry and wet systems of waste disposal are the methods most used. Neither method utilizes litter such as straw. Each method combines collection, removal, storage, treatment, and disposal.

Dry Systems

Feces usually contain 70 to 80 percent moisture at time of expulsion, and each 1,000 layers produce about 4 ft^3 or 250 lb per day. Information on the range in manure production and composition is given in chapter 4.

Treatment or Drying

In southern areas the manure can be dried successfully under cages in open houses with good air circulation and with two birds per cage. Drinking water for the birds should not be allowed to spill or overflow onto the manure.

Coning and drying are usually sufficient to prevent odor and fly breeding most of the year. Odor and flies are not usually a problem over the short period when coning and drying do not occur.

In northern areas various inhouse drying methods have been successfully used. One method allows the waste to fall onto a platform; scrapers and air moving across the surface turn the waste and increase evaporation. In addition to the housing ventilation at the rate of 3 to 4 ft^3 per minute per bird, an auxiliary blower increases the air movement over the manure surfaces. This method under favorable humidity conditions reduces the moisture of the waste to 25 or 30 percent. Drying eliminates odor and fly-breeding problems.

Collection

The manure is collected inhouse and removed frequently or allowed to accumulate in deep pits. If the pits or collection areas are shallow, frequent cleaning is required.

Removal

Equipment for removing the manure varies with the method of drying and amount of storage. Equipment may consist of a garden tractor with a side arm for removing the wastes under birds on suspended floors. Tractors with scrapers or front-end loaders are often used in deep pits. Various types of mechanical or conveyor cleaners are used and are

especially practical for houses 300 to 400 ft or more long. If mechanical cleaners are used, the investment is higher, frequent waste removal is necessary, and good maintenance is required.

Storage

There are times in any area when it is undesirable or impractical to haul or spread manure. Pits about 4 ft deep under stair-step cages or slatted-floor housing will hold the manure from a full laying cycle, 13 to 15 months. If inhouse storage is small, additional storage facilities are needed.

Disposal

Conventional spreaders can be used if there is proper storage and if drying is adequate. Flail spreaders will handle any material, even frozen, but these spreaders have limited capacity and require more power to operate.

Spreading manure on cropland is the most common practice of waste disposal in agriculture. The manure should be applied to the utilization area at times and at rates that do not result in polluted runoff, excessive odor, or damage to crops.

Commonsense management is needed for any land applications of manure. Points to consider are odor and pollution controls and nutrient utilization. The manure should be plowed or disked under soon after spreading. Spreading should be timed for seasons when people are not living outdoors or having windows open. Hauling and spreading should be done when the wind is in the right direction, relative humidity is low, and drying is rapid. Refrain from spreading in late afternoon or evening except in remote areas. For application amounts see chapters 5, 6, and 11.

Wet Systems

Collection

The droppings can be collected in shallow or deep pits or deposited directly into an oxidation ditch. Undercage or underhouse collection pits without aeration become anaerobic; hence, they should be cleaned frequently and the wastes stored in holding tanks or spread on the land.

Removal

Several methods can be used to move the waste to storage. A floating-dam flood system is simple and practical and requires little labor. The dam is constructed of 2 inch by 6 inch or similar lumber and has a flat top. Its height is sufficiently less than the depth of the pit so overflow can occur without liquid spilling over the side of the channel. The dam is placed at the upper end of the pit, and water is pumped behind the dam at a rate of about 100 gallons per minure (gal/min). As the liquid depth builds, the head pushes the dam along the channel, scraping solids with it. When the load builds in front of the dam, overflow dilutes the wastes and adds lubrication, which allows the dam to continue to the lower end. The waste effluent dumps into a cross channel and flows from the building. A settling facility allows reuse of some

of the water. When the dam reaches the lower end, it is carried back to the head of the next channel to be cleaned. Channels are usually cleaned at least once a week. In some deep pits false-end gates pulled by a winch are used for cleaning if gravity loading is possible. Some shallow pits are cleaned by flushing with water or by mechanical scrapers.

Storage

Pits about 3 ft deep under stair-step cages hold 6 months of droppings. If shallower pits are used, liquid-holding tanks can be used for additional storage.

Agitation and removal of contents from liquid storage are accomplished in the same manner as in any liquid manure system. Removal and land application can be by tank spreaders, soil injection, or sprinklers.

Wet systems for poultry are undesirable because of odor. Oxygen should be supplied to control odor or more nearly complete treatment such as aeration or oxidation ditches should be provided.

Processing

Oxidation ditches and aerated lagoons can be designed and operated as described in chapter 12. Research is not complete on diffused aeration components of waste management systems for poultry manure. However, both surface and diffused aeration can be designed to operate satisfactorily. Oxygen transfer rates for a diffused aeration system are less than for surface aeration. Diffused aeration systems must have lower loading rates or more horsepower must be provided to transfer enough oxygen.

In a pilot plant at Cornell University, an oxidation ditch directly below 250 birds is aerated by surface aerators. Typical or not, because of the high evaporation rate achieved, there has been no overflow from the system in 18 months. This oxidation ditch serves as a long-term aerated storage facility and can be pumped out for land application of wastes when conditions are favorable.

Lagoons can be used in favorable climates. Their use in northern areas usually is not practical because of odor from the anaerobic-type lagoon and the surface area required for the aerobic type.

Disposal

Disposal from aerated systems can be run by direct application to land or the overflow can be run through a separation unit to remove the solids. The removed solids can then be applied to the land and the liquid can be either treated further or applied to the land.

3. DUCKS

GENERAL

Well over 50 percent of the ducks raised in the United States are produced on Long Island, N.Y. The discussion of waste management systems that follows is drawn from data gathered from the Long Island duck producers.

CLASSIFICATION OF SYSTEMS

In "Effluent Guidelines and Standards" set forth in the Federal Register of Feb. 14, 1974, facilities for housing of ducks are given as dry lot or wet lot and defined as follows:

> "The term 'dry lot' shall mean a confinement facility for growing ducks in confinement with a dry litter floor cover and no access to swimming areas.
>
> "The term 'wet lot' shall mean a confinement facility for raising ducks which is open to the environment with a small portion of shelter area, and with open water runs and swimming areas to which ducks have free access."

SYSTEM COMPONENTS

Waste management systems for duck farms on Long Island today incorporate swim water, aerated lagoons, settling ponds, and chlorination. The effluent is discharged to public water such as that of bays, coves, estuaries, and streams. Some systems include a solids separation unit between the swim water and the aerated lagoon.

OPERATION

Generally, the duck farms are situated along streams, coves, and estuaries where there are sloping sandy shorelines, an abundance of fresh water, and a mild climate.

In a typical operation, the ducks from time of hatching to 14 days are kept in confinement on litter or wire flooring. From confinement they are moved to duck yards and grouped by age along a flowing channel (swim water) until slaughter. The life of a bird is 6 to 7 weeks.

The swim water is located along the low edge of the duckyard. Its sources are the ground-water supplies or diversions from fresh-water streams.

The swim-water channel is designed to provide 1/2 to 1 ft^2 of water per duck and a normal water depth of 4 to 6 in.

A large part of the duck's time is spent out of water, and large amounts of waste accumulate on the shoreline of the duck yard near the swim water. These wastes are flushed into the swim-water channels (duck runs) by surface runoff during rainstorms. Some producers scrape the yards when wastes accumulate.

In addition to runoff, substantial seepage from ground water adds to the swim water during and following above-normal rainfall cycles. Treatment must therefore be flexible enough to handle variations in flow rate and waste quantities.

The flowing water and the agitation provided by the ducks in the swim water transport the wastes through the channels to the treatment facilities.

The waste water from swim-water channels contains large amounts of sand, manure particles, and undigested feed. Some systems include a separation unit to remove the solids, and in other systems the waste water is pumped directly to aerated lagoons. Detention time in the

aerated lagoons varies in accordance with hydraulic loading. The range is 3 to 8 days; the average is 5 days.

The effluent from the aerated lagoons passes into a settling pond for further removal of settleable solids. Usually there are two or three settling ponds used alternately to allow cleaning.

The effluent from the settling ponds next passes through a chlorine contact chamber to reduce bacteria and coliform counts. The effluents are then discharged to public waters.

SYSTEM HYDRAULIC LOAD

The treated wastes from duck farms have been meeting set standards except during periods of hydraulic overloading from runoff and groundwater accretion. This hydraulic overloading of the treatment system has been termed the most serious problem. Therefore, water control, both surface and subsurface, is essential in waste management systems.

Surface and subsurface water control should consider incorporation of appropriate measures and practices as follows:

Surface Water

A. Buildings
   1. Gutters and downspouts into dry wells
   2. Roof water to gravel trench
   3. Concrete gutters or underground outlets to carry roof water to unpolluted water disposal system
   4. Shed-roof design of new buildings to divert roof water from duck yard

B. Onfarm areas, excluding duckyards
   1. Diversions
      a. Underground outlets
      b. Surface outlets
      c. Dry wells where sedimentation is low
      d. Outlet to fresh-water ponds
   2. Channels
      a. Pavement or riprap along roadways as needed
      b. Outlet into sumps, recharge basins, or borrow pits

C. Off-farm areas
   1. Recharge basins with overflow bypassing duckyards
   2. Diversions
   3. Leaching catch basins (small drainage areas)
   4. Channels through the farm to conduct unpolluted runoff
   5. Diking

D. Onfarm areas (duckyard water)
   1. Minimum yard area
   2. Temporary storage
      a. In swim-water area
      b. In holding ponds (by gravity or pumping)

Subsurface Water

A. Subsurface drains
B. Wellpoints
C. Swim water relocated above maximum ground-water level

FUTURE REQUIREMENTS

Regulations issued by EPA under Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972, require that duck feedlots have no discharge by 1983. To meet these regulations future waste management for duck farms will need techniques similar to those on beef, dairy, swine, and poultry feedlots, such as:

1. Diverting unpolluted water
2. Minimizing duckyard area
3. Collecting, treating, and/or storing polluted runoff
4. Disposing on utilization areas at times and at rates that do not cause runoff, excessive odor, or damage to crops

Careful management and use of water recycling measures to minimize water use will be necessary if the 1983 effluent standard is to be met.

PART V - SHEEP AND HORSES

The types of waste management systems suitable for cattle and swine are generally also suitable for sheep and horses. Most large-scale sheep herding or pasturing is done in the arid and semiarid regions on open rangeland, on land leased from the Forest Service or the Bureau of Land Management, and on range and pasture land owned or leased by privately operated ranches. Waste management is usually no problem since animal waste is deposited over large areas and recycled naturally on the land. The few confined operations include those for breeders and special purposes, and the animal waste from them is generally spread on the land in the same manner as waste from feedlots, dairies, etc. Animal waste from sheep, about 4 lb per day per animal, is considerably less than that from dairy and beef cattle. The biochemical oxygen demand of sheep manure is relatively low as compared to cattle wastes.

Today horses are limited almost exclusively to riding horses on large cattle ranches and plantations and to horses ridden for recreation, show, and racing. Except for periods of inclement weather, most horses are on pasture and the animal wastes are dispersed over sizable areas where they are recycled naturally on the land.

Wastes do accumulate in stables and other areas during periods of confinement. Except for locations such as large race tracks, riding stables, or breeding facilities, the volume is small and the wastes are manually scraped and loaded onto conventional manure spreaders and spread on the land. The wastes from horses are similar to those from cattle but the volume is smaller (about 40 to 60 lb per day for a 1,000 lb animal).

See chapter 4 for a more detailed discussion of characteristics and daily production of wastes from sheep and horses.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 10. FOOD PROCESSING WASTE MANAGEMENT SYSTEMS

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CHAPTER 10. FOOD PROCESSING WASTE MANAGEMENT SYSTEMS

1. SCOPE

The treatment and disposal of food processing wastes are discussed in this chapter. The wastes considered are those from fruit and vegetable canning and freezing, milk processing plants, and slaughterhouses. The use and limitations of separation, lagoons, oxidation ditches, and land application or recycling are discussed.

Not discussed are the planning, design, or construction of in-plant facilities such as separators, clarifiers, precipitators, digestors, activated sludge systems, sand filters, evaporators, dryers, chlorinators, scrubbers, etc. These are considered the province of industrial plant design and construction and are not within the scope of SCS activities.

2. GENERAL

Generally speaking, the wastes from food processing systems are not difficult to treat. Some segments of the food processing industry have wastes that require special treatment, but most wastes can be treated by conventional means. Wastes from cannery and meat processing industries are characterized by a high organic load and a relatively low nitrogen and phosphorus content.

Most food processing plants operate on a seasonal basis, and the organic load in waste materials may fluctuate widely throughout the month or even one working day. Wastes from food processing plants may have a BOD equal to many times that of raw sewage. Fresh wastes from food processing usually do not have offensive odors or contain pathogenic organisms, and they react favorably to biological treatment. However, the BOD may be considerably higher than that of municipal sewage.

Most large-scale food processing plants now have primary and secondary treatment facilities that adequately meet their needs. Future efforts should be toward increased efficiency of secondary plants, refinement of conventional methods, development of processes capable of a higher degree of treatment or closed loop systems where the treated effluent is reused, and processing methods to reduce the quantity of water required and waste produced. Efforts should also be made toward developing profitable byproducts from waste materials and recycling through land disposal.

Food processing plants usually have three choices for final disposal of their unused waste materials: a municipal sewage system for treatment along with municipal sewage, aerobic and/or anaerobic lagoons or oxidation ditches, or application directly to land. The proper choice depends on economics, technical considerations, volume and composition of effluents, degree of treatment required, climatic

conditions, size of municipal sewage plant, and the land available for the disposal. Final disposal may be a combination of these, e.g., from lagoon to the land or to municipal sewage plants.

In the past many food processing plants discharged treated effluent directly to streams or municipal sewage plants. But with stricter legal requirements and increased stress on municipal facilities, the current trend is to land disposal. Soil recycling of raw cannery wastes is now receiving considerable attention.

3. METHODS OF TREATMENT

The methods for treating food processing wastes are many and varied. Some of the older methods used facilities common to conventional sewage treatment, such as separators, clarifiers, digestors, sand filters, and chlorinators, and the treated effluent was discharged to natural streams. Treatment research has recently shifted toward the recycling of raw or partially digested wastes. This recycling uses separators, settling basins, aerobic and anaerobic lagoons, and land application through sprinkler systems patterned after conventional irrigation systems. A brief discussion of some of the facilities now commonly included in food processing waste management follows.

SEPARATION

Separation is the process of separating solid wastes from liquid wastes by screening, sedimentation, clarification, flotation, etc. Separation is usually the first step in treating food wastes for disposal. In food processing the solid wastes consist of skin, peelings, cores, seeds, vines or stems, and pulp from the preparation of fruits and vegetables for canning, freezing, pickling, and other forms of preservation. Separation is also used for wastes from slaughterhouses, milk processing, and seafood processing. After separation, the solid wastes can be spread directly on land for recycling, processed for cattle feed or for fertilizer, dehydrated, composted, or placed in sanitary landfills. The liquid wastes containing varying amounts of suspended or dissolved solids can be applied directly to the land through sprinkler systems, routed through conventional waste treatment plants, routed to aerobic or anaerobic lagoons, or stored in holding tanks or pits for later treatment and disposal. Recent research with oxidation ditches indicates that they may have considerable merit for treating liquid and slurry wastes.

AEROBIC LAGOONS

Aerobic lagoons are shallow, 2 to 5 feet deep, and depend on natural aeration for oxygen. This type of lagoon has not proved satisfactory for treatment of food processing wastes since the BOD and surface area requirements are too high.

AERATED LAGOONS

Aerated lagoons are equipped with mechanical aerators to supply the oxygen required for aerobic treatment of wastes. There are several types of mechanical aerators. The floating type, which is easily maintained and can be used on almost any type of lagoon or basin, seems to be the favorite with the food processing industry. Since mechanical aerators agitate the lagoon contents to considerable depths, aerated aerobic lagoons can be deep, thereby reducing the land area needed. This type of lagoon is often called an aeration basin. The treatment is actually a mixed activated sludge process. Because of the additional oxygen supplied to aerated lagoons, the loading rates can be much higher than for naturally aerobic lagoons.

Clarifiers are often included with aerated lagoons. Part of the sludge from the clarifier can be recirculated. This process is called seeding, since the micro-organisms in the sludge are recirculated to the lagoon or lagoons.

Because food processing wastes are high in BOD and low in nitrogen and phosphorus, nitrogen and phosphorus are often added to the lagoon contents to get the best digestion possible. The rate at which organic matter is used by micro-organisms often depends on the concentration of a limiting nutrient. In food processing wastes, as compared with municipal sewage, nitrogen and phosphorus are often limiting nutrients.

Many food processing operations, especially canning, are seasonal and are shut down for periods of several months. Aerobic lagoons are not well suited to these seasonal plants because a start-up period is needed to generate vigorous micro-organism activity. Aerated aerobic lagoons, which are relatively free from strong odor, can be used in or near populated areas.

ANAEROBIC LAGOONS

Anaerobic lagoons are deep lagoons that function in the absence of oxygen. They have not been used extensively in the general food processing business except for meat processing. The anaerobic process requires less nitrogen and phosphorus for digestion and may produce less sludge. Because anaerobic lagoons can be highly odorous and thus are generally not acceptable in populated areas, they have not been used extensively for food processing wastes. Start-up time is less for anaerobic lagoons than for aerated lagoons, which is an advantage for seasonal plants. If located in an area where odor is not a problem, anaerobic lagoons are generally better suited to the food processing industry than aerobic lagoons.

OXIDATION DITCHES

Treatment of food processing wastes by oxidation ditches is still in the experimental or trial stage. Oxidation ditches are closed-circuit ditches, circular or oval, and are usually lined with concrete. A ditch is equipped with one or more paddle-wheel agitators that keep the waste

materials flowing in the ditch. Agitators also introduce oxygen and aerate the slurry waste.

Basically, an oxidation ditch is a form of activated sludge treatment using relatively simple equipment as compared with that in municipal sewage treatment plants. The process is aerobic, and odor is not a problem. Oxidation ditches are under test for animal waste disposal but have not been used very much by food processing industries. The digestive process in oxidation ditches is essentially the same as in aerated lagoons, and they have the same general advantages and disadvantages.

4. LAND APPLICATION OF WASTES

Land application of wastes is a method of recycling that uses both aerobic and anaerobic processes. Wastes are applied to the land in liquid, slurry, or solid form, depending on the type of waste and the method of disposal. The success or failure of land recycling depends on factors such as composition of the waste, soil and subsoil conditions, vegetation, climate, etc. The wastes undergo aerobic decomposition at or near the soil surface. Nutrients and other components are tied up in the soil or utilized by vegetation.

APPLICATION OF FRESH SOLID WASTES

The first step in processing fruits and vegetables for canning, freezing, or preserving is to wash, peel or skin, and remove the cores, seeds, and stems. The solid waste from this first step is mostly organic, although there may be some silt and sediment from the washing. The second step is to put the slurry waste through a separator, the most common being vibratory screens, to remove most of the solids. These fresh solids are about 85 percent water, are free from odor, and do not contain pathogenic organisms.

The most common way to apply these solid wastes to land is by dump truck and mechanical spreaders similar to those used for solid animal wastes. Additional spreading or floating may be necessary for the desired uniformity of application. The wastes are allowed to dry for about 2 days and then disked or plowed into the soil. Management is directed toward prevention of flies and excessive odor and varies considerably with local climatic conditions. To date the best results have come from one application a year followed by seeding to an annual crop. Plant nutrients released in the process become available for recycling by subsequent plant growth.

Food processing wastes vary considerably because of the great variety of foods and chemical processes involved; but, generally, fruit and vegetable wastes contain about 1 to 2 percent (dry weight) nitrogen, which is usually the limiting nutrient. If it is assumed that 300 lb nitrogen per acre per year is a reasonable application, then about 15 tons per acre (dry weight) of solid waste from the separator could be applied. See chapter 4 for characteristics of various wastes and chapters 5, 6, and 11 for loading rates consistent with soil and plant conditions.

APPLICATION OF LIQUID AND SLURRY WASTES

Liquid and slurry wastes from food processing may undergo various degrees of digestion, from none to almost complete, as with effluent from activated sludge treatment or from aerated lagoons, before being applied to land. Because the composition of waste effluent from food processing plants varies, it is necessary to consider each effluent individually before planning final disposal. Effluents from processing green beans, squash, tomatoes, corn, and steam-peeled potatoes are usually suitable for land application. The effluent from processing peas and lima beans may not be suitable because the high concentration of sodium and chloride can affect infiltration and permeability of the soil. Effluent from lye-peel processes used for potatoes is not usually suitable for direct land application because the high concentration of sodium can damage soil structure. See chapters 5, 6, and 11 for data on allowable rates of application for soils and vegetation. A discussion of some common methods of land disposal and recycling of liquid and slurry wastes from food processing follows.

Sprinkler or Spray Application

In this method the common irrigation systems are used, but some of the equipment must be adapted for waste application. The slurry from holding tanks, ponds, and lagoons may contain a considerable amount of solids in suspension that plug most ordinary irrigation sprinklers. Specially designed sprinklers, called volume guns, with nozzle openings of 1 inch or larger, clear most solids found in slurry. Volume guns are available commercially.

If the slurry contains large solids, a chopper can be attached to the pump or a specially designed chopper pump can be used. Pumps, pipes, and fittings commercially available from irrigation supply sources are usually adequate for disposal of liquid and slurry wastes. The rate of application of waste effluent must not exceed the infiltration rate of the soil to which it is applied, and the total application should be within recommended rates.

Disposal of wastes by sprinkling should not be confused with ordinary irrigation. The purpose of ordinary irrigation is to provide enough soil moisture to meet the consumptive use of the crop or vegetation being grown. The purpose of waste disposal is to dispose of the maximum amount of waste consistent with soil and vegetation conditions. In arid and semiarid regions where irrigation is practiced, the amount of moisture supplied by the waste effluent is usually not enough to meet the consumptive requirement; additional irrigation water may have to be applied for the crop or vegetation grown. In humid areas the opposite may be true, and the limitation on application of waste may be the amount of water present in the waste.

Spray-Runoff Application

Spray-runoff application is a special adaptation of sprinkler systems and is used on grasslands. The slope should not exceed about 6

percent, and the land should be terraced and seeded to an adapted grass. The rate of application of the waste effluent is in excess of the infiltration rate. Solids are filtered out in the grassland between the terraces, allowing partially treated liquid wastes to reach the terrace. The solids are left to be decomposed in a relatively dry condition. The liquid receives further treatment in the terrace channel.

Infiltration Basins

Using infiltration basins for waste treatment is an adaptation of basin irrigation systems. The land is divided into basins, each of which is leveled, diked, and seeded to an adapted grass. The basins are alternately flooded with waste effluent and additional water as necessary, to supply the soil moisture necessary for plant growth. Part of the effluent and the supplemental water seeps into the soil where it undergoes further renovation. With this system care must be exercised to select a site with moderately well drained soils and a normal water table some distance below the surface. If the site does not have good natural drainage, subsurface drains should be installed before the basins are constructed. The drains should be at least 5 feet below the surface. To prevent soil clogging, the period between applications of wastes should be long enough for the deposited solids to dry and decompose.

Plow Furrow Application

This is a type of application by which the wastes, solid or slurry, are put into a trench or furrow 6 to 12 inches deep and then immediately covered with soil. This reduces odor. Several types of equipment can be used, such as honeywagons with special furrowing attachments and cultivators with special sweep attachments. Considerable research is underway to develop special equipment for this purpose. Trenches in which the wastes are covered to a 1-ft depth of soil are also being studied.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 11. LAND APPLICATION OF WASTES

Compiled by Grant W. Woodward, water management engineer (ret.), SCS, Lincoln, Nebr.

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Tables

CHAPTER 11. LAND APPLICATION OF WASTES

1. GENERAL

Most of the wastes from livestock and poultry and much of the sludge material resulting from municipal waste treatment are applied to land. Large quantities of food processing wastes and some effluents from municipal waste treatment plants are also applied to land.

This chapter describes methods of land application and lists cautions and restrictions for specific methods. Related helpful information is given in other chapters. Chapter 4 explains the characteristics of various waste materials after they have undergone specific treatments. Chapter 5 gives the requirements of various types of soil for the application of different wastes, and chapter 6 discusses the utilization of these products by various plants.

States have specific laws about water quality, odor, appearance, or other requirements that must be respected in the disposition of any waste products.

A land application plan must include the type, form, and volume of waste materials to be handled. It must consider the kinds and amounts of nutrients, chemicals, and other components of the material to be disposed of. The wastes may be solid, slurry, or liquid in form.

2. SOLIDS

Solids are produced by a wide variety of municipal, commercial, industrial, and agricultural operations. Animal production units, particularly feedlots, yield large quantities of solid organic wastes to be disposed on land.

Generally, spreaders or dump trucks carry these wastes to the land. Dump trucks usually need additional equipment for spreading the wastes uniformly over the land surface. The wastes should not be spread when the ground is frozen. They should be covered when necessary to prevent odor or runoff water from polluting watercourses. A stacking area is generally necessary for solid livestock wastes. The material from earth feedlots can be put in mounds during the winter months or periods when growing crops make the land unsuitable for spreading.

Manure in stacks or mounds loses much soluble nitrogen by volatization or denitrification. A ton of barnyard manure contains from 2 to 20 lb total nitrogen. The nitrogen content usually determines the maximum amount of manure that should be applied annually per acre. It should also be noted that in some places, as where crop production is not of major importance, the application of wastes must be based more on capability of the soil to assimilate the waste than on capability of crops to utilize the nutrients. Because of the variable content of plant nutrients in solid manures, a chemical analysis should be made whenever substantial amounts are to be applied to the land.

Disposition of relatively dry solid manure on the land generally does not result in noticeably offensive odor unless rain falls before the material is incorporated into the soil.

3. SLURRY

Slurries generally come from confined feeding facilities for cattle, hogs, and chickens, or as sludge from municipal waste treatment plants. This material can be transported to land by either honeywagons or pumps and pipelines. Because of time and labor requirements, pumps and pipelines are generally more economical for transporting large volumes of slurry. Figures 11-1 and 11-2 compare time required for hauling with that for pumping. Slurry can be applied to the land by sprinklers, by broadcasting from slurry tanks, by application through flooding or in furrows, or by injection under the ground surface.

Sludge from municipal waste treatment plants normally has a solids content of 3 to 7 percent. The hydraulic characteristics are similar to those of water, and the sludge can be handled by most types of sprinkler equipment.

The slurry material from confined livestock facilities is too thick to spread efficiently with irrigation equipment, but, if properly agitated, it flows readily to pump inlets. It may have a solids content up to 10 or 15 percent for swine and cattle manure and up to 20 percent for poultry manure. Unless these materials are diluted to a liquid consistency, they are generally pumped into honeywagons by high-capacity, low-head pumps or are drawn into the wagons by vacuum pumps. Additional water is frequently required for agitation.

Slurry can be broadcast on the land from honeywagons, but because of odor and the danger of polluting surface water, it is better to discharge the material into furrows and bury it with a plow.

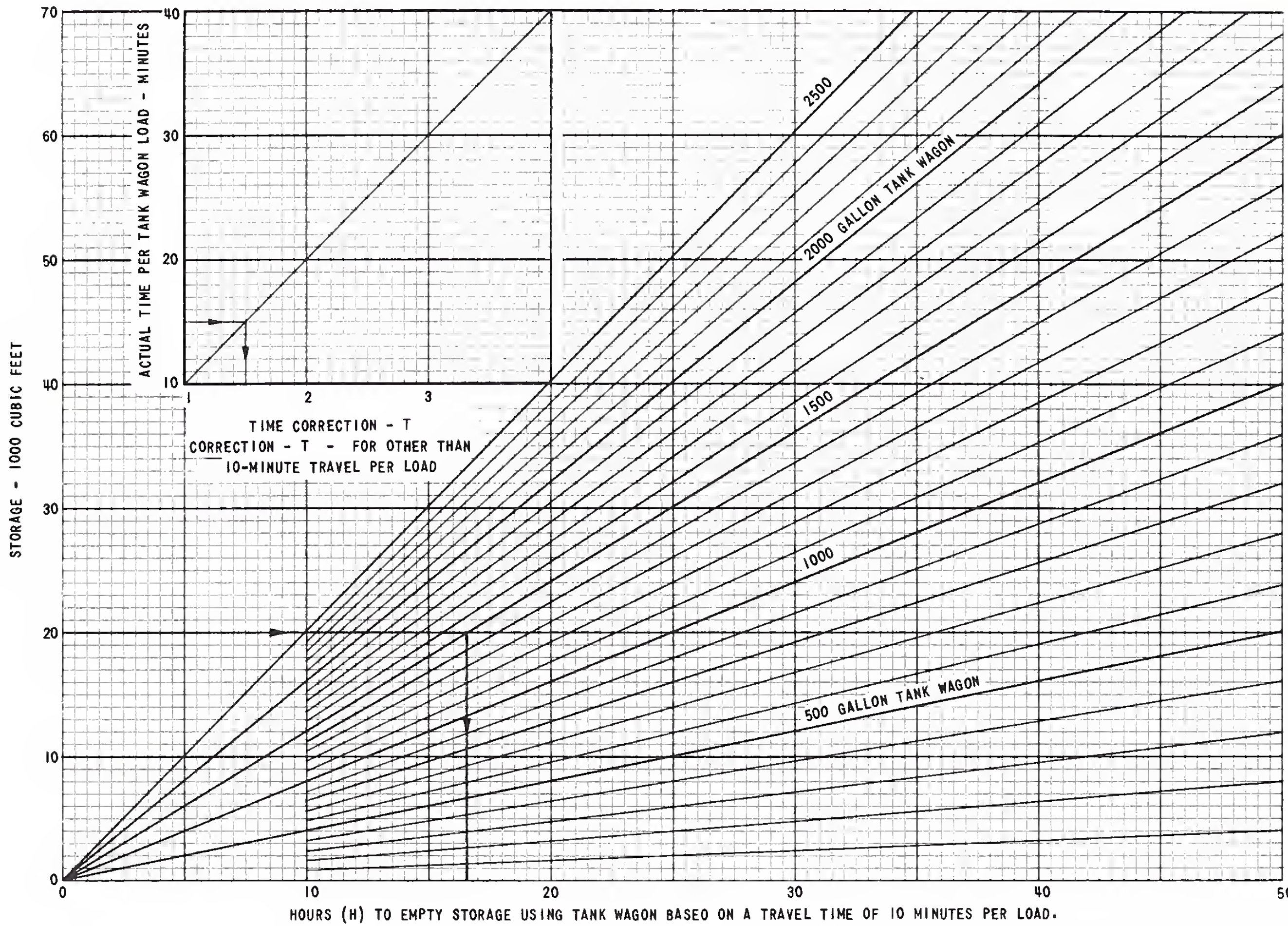
Swine and poultry manure of approximately 12 percent solids content and cattle manure of approximately 7 percent solids content can be pumped into honeywagons or handled with irrigation equipment that has low-capacity, high-head pumps with chopping blades and large gun-type sprinklers.

Materials diluted to less than approximately 7 percent solids content for swine or poultry manure and 4 percent for cattle manure can be handled by almost any irrigation equipment, such as standard centrifugal pumps, regular sprinkler nozzles, or gated pipe and furrows. If the material is distributed in graded furrows, tailwater should be recovered to prevent runoff from polluting surface waters.

The amount of water needed to dilute manures to a specific pumping consistency can be determined from figure 11-3. For example, assume that cattle manure with 20 percent solids content must be diluted for use with a standard irrigation sprinkler. The maximum solids content should be 4 percent. According to figure 11-3, 30 gal water per cubic foot of manure is needed.

The following are important characteristics of different manures in slurry form:

1. Poultry manure is heavy and dense and usually settles to the bottom with a liquid layer forming on top.



EXAMPLE:

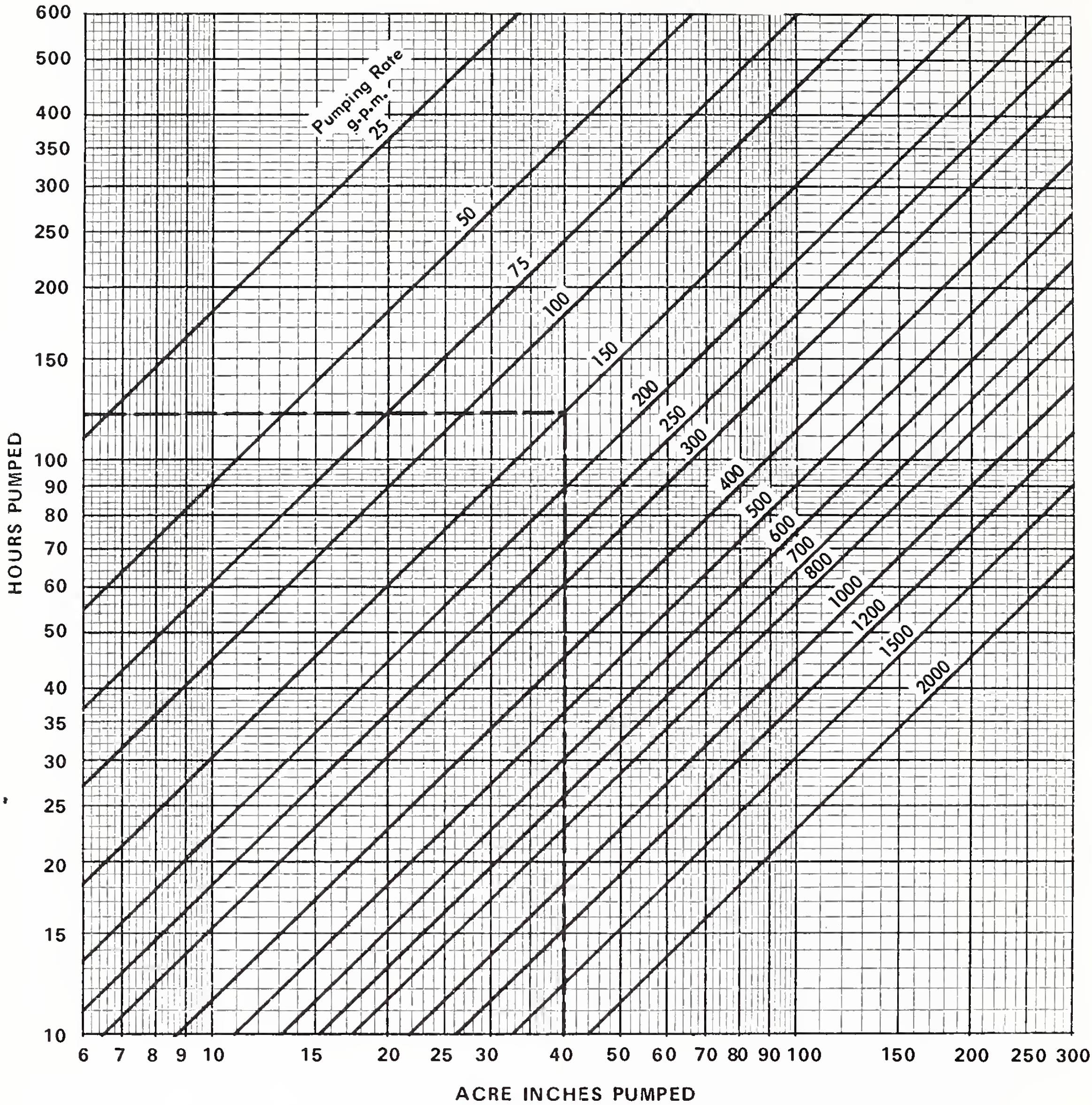
GIVEN:
STORAGE TO BE EMPTIEO - 20,000 CUBIC FEET
TANK WAGON - 1,500 GALLONS
ACTUAL TIME PER LOAO - 15 MINUTES

SOLUTION:
FROM CHARTS - H = 16.6, T = 1.5
TOTAL TIME TO EMPTY 20,000 CUBIC FEET
16.6 X 1.5 = 24.9 HOURS

CHART TO CALCULATE TIME TO EMPTY STORAGE FACILITY BY VARIOUS SIZE TANK WAGONS

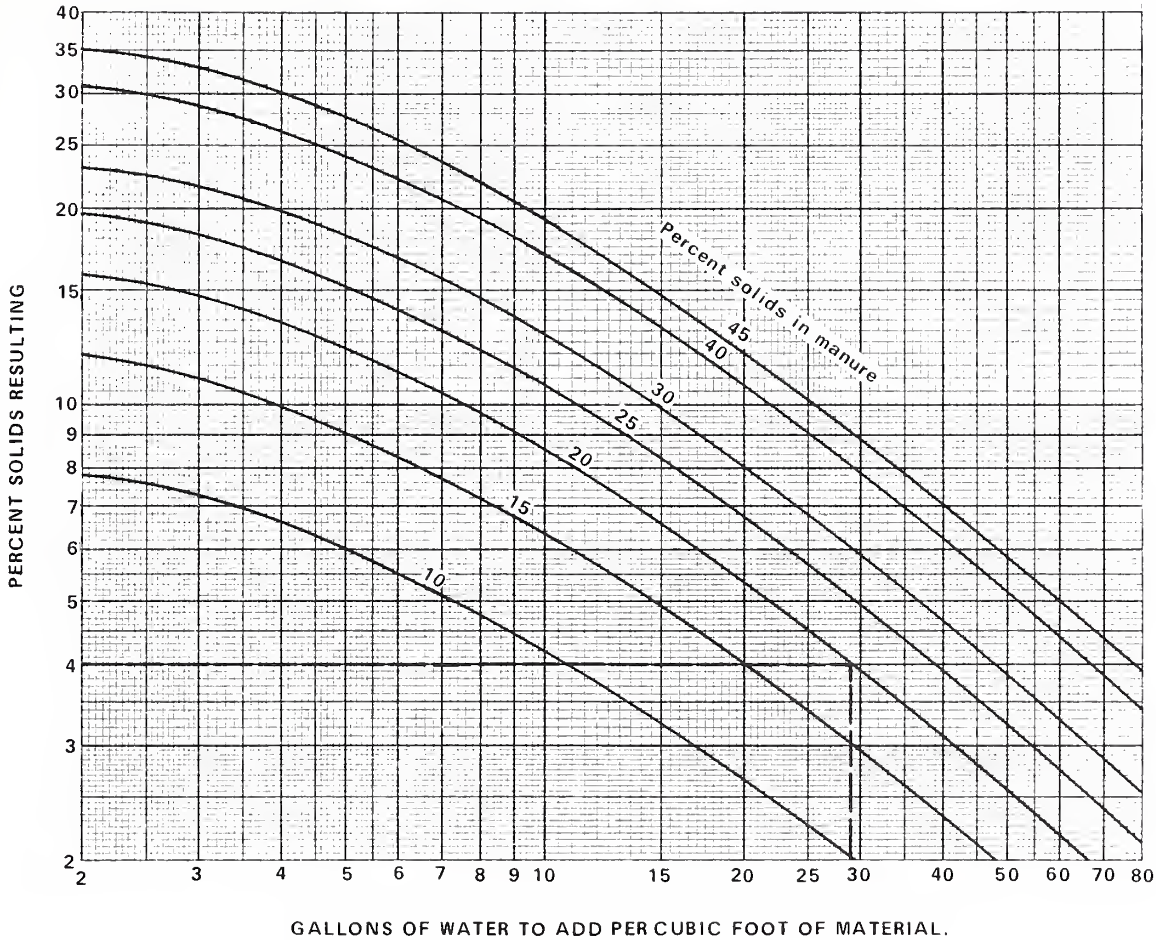
5,N-31,331

Figure 11-1.--Time required to empty storage facility by various size tank wagons.



Example: Pumping rate 150 g.p.m. Pumping time 120 hours. Acre inches pumped is 40 or 3.33 acre feet.

Figure 11-2.--Acre-inches pumped in given time at various pumping rates.



EXAMPLE:

Cattle manure containing 20% solids. It is desired to dilute to 4% solid content for disposal through standard sprinkler equipment. Select 4% solids on left side and 20% solids curved line. Below this intersection read 29 gal. per cu.ft. of waste material.

Figure 11-3.--Gallons of water required per cubic foot of material for dilution to pumping consistency.

2. Swine manure tends to remain in suspension.
3. Cattle manure usually rises to the top and forms a solid layer.

Manures in slurry form are particularly odorous. Manure slurry in disposal areas near residences should be applied below the soil surface or be immediately covered.

The amount of nitrogen being applied is relatively simple to determine from data in chapter 4 or, preferably, from sample analyses.

4. LIQUIDS

Liquid manure generally is produced in open or partially enclosed feeding operations or by dilution of manures with wash water in

confined facilities. Rainfall or snowmelt carries the manure from the feedlot, preferably through a settling basin, to a holding pond.

The liquids can be handled by any type of sprinkler or through gated pipes into furrows or borders. If adequate water is available for irrigation, the disposal system can be designed for maximum use of the manure for crop fertilization. The waste disposal system can often be tied into a tailwater recovery pit for surface irrigation.

If the supply of water is limited, the primary purpose of waste management is disposal of unwanted materials. The amount of wastes that can be safely disposed of depends on the ability of the soil and crop to assimilate the applied effluent.

5. VOLUME OF APPLICATION

The volume of application should be such that polluted waters are not forced into underground water supplies and that runoff does not pollute surface waters. The solids in slurries or liquids may form a sealing crust over the soil and restrict intake. This crust flakes when dried, which permits normal intake again. For this reason small applications at a time, usually less than 1 inch, should be made with a sprinkler system.

Feedlot runoff in a holding pond may contain from 200 to 5,000 lb of nitrogen per acre-foot. The liquid in a specific pond should be analyzed periodically to determine the nitrogen content. Salt content may also be critical, particularly in arid areas.

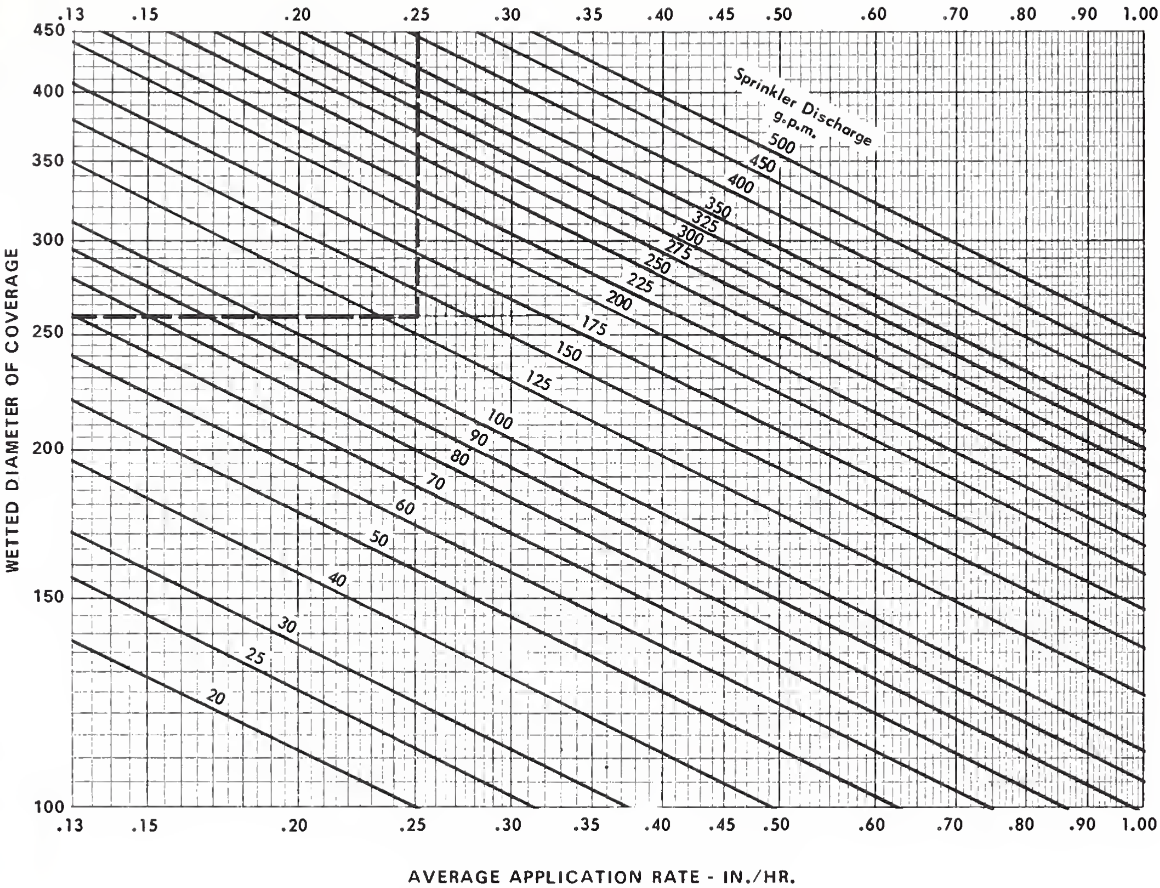
It is important to know the concentration of various components in wastes to determine the volume that can be safely applied and assimilated by the soils and plants.

6. APPLICATION RATE

The application rate for wastes must be selected to fit the intake rate of the soil. Suggested application rates for liquid waste effluents are usually less than three-fourths of the recommended rate for irrigation water. Local experience should determine the maximum permissible application rate. Sprinkler systems for effluent disposal may include a wide variety of equipment. Traveling big guns with sprinklers covering about seven-eighths of the circle and leaving a dry area, one-eighth circle in front of the gun, are common. Figure 11-4 shows average application rates for sprinklers of various capacities. The application rate for a gun covering seven-eighths of the circle would be eight-sevenths of the rate indicated in the figure.

7. EXAMPLE OF PLAN FOR LAND APPLICATION OF LIVESTOCK WASTES

Assume that an 0.5-acre concrete-surface feedlot at Peoria, Ill., is used for 300 steers that weigh an average of 800 lb each. The operator grows corn for silage. With this basic information, a plan for land application of the waste could proceed as follows.



Example: Rainbird Model 105AFP with 7/8" ring orifice at 70# pressure. This nozzle has wetted diameter of 258' and discharges 132 g.p.m. (Rainbird Catalog) from the chart above. Average application rate is approximately 25" per hour. If mounted on a traveling gun and set to cover 7/8 of a circle, the average application rate would then be 8/7 x 0.25 = 0.29 inch per hour.

Figure 11-4.--Average application rate for sprinklers of various discharge rates and diameters covered.

LAND REQUIREMENT

300 head at 800 lb = 240,000 lb live weight. Nitrogen (N) produced is about 140 lb per 1,000 lb live weight per year.

$$\text{Total N} = \frac{240{,}000 \times 140}{1{,}000} = 33{,}600 \text{ lb/yr}$$

Approximately 75 percent of N produced is lost from the feedlot and from storage.

$$\text{N to be applied} = 0.25 \times 33{,}600 = 8{,}400 \text{ lb}$$

Approximately 200 lb N is used by corn per year.

$$\text{Acres needed} = \frac{8{,}400}{200} = \text{approximately 42 acres}$$

STORAGE RESERVOIR REQUIREMENT

Average annual precipitation at Peoria is 34.8 in. Average annual evaporation at Peoria is 33 in. Therefore, little added storage is needed for precipitation falling directly on the reservoir surface.

Monthly rainfall and runoff data for the feedlot follow. By using runoff curve No. 95 (CN 95), the design is conservative and provides a factor of safety. As shown in part VI of chapter 12, using a runoff curve number as low as CN 86 generally is acceptable for computing 30-day runoff.

Month	Rainfall (Inches)	Runoff (using CN 95) (Inches)
January	1.88	1.37
February	1.71	1.21
March	2.85	2.30
April	3.97	3.40
May	4.27	3.70
June	4.08	3.51
July	3.54	2.98
August	2.88	2.33
September	3.05	2.50
October	2.53	1.99
November	2.14	1.62
December	1.94	1.43
Total	34.84	28.34

Runoff of 28.34 inches from 0.5 acre = 14.17 acre-in. or 1.2 acre-ft of storage required for rainfall runoff.

Based on a manure production figure of 1.0 ft^3 per 1,000 lb live weight per day the annual manure production figure is obtained as follows.

$$\frac{240{,}000}{1{,}000} \times 365 = 87{,}600 \text{ ft}^3 = 2.0 \text{ acre-ft/yr}$$

Total storage needed is 1.2 + 2.0 = 3.2 acre-ft, exclusive of additional storage needed for 10-year or 25-year, 24-hour runoff as discussed in part VI of chapter 12.

SELECTION OF LAND APPLICATION EQUIPMENT

The addition of 1.2 acre-ft of runoff to 2.0 acre-ft of manure adds $\frac{1.2}{2.0}$ or 0.6 ft^3 of dilution water per cubic foot of manure

$$0.6 \text{ ft}^3 = 0.6 \times 7.48 \text{ gal/ft}^3 = 4.5 \text{ gal water/ft}^3 \text{ manure}$$

Assume that cattle manure is 18 percent solids. From figure 11-3, addition of 4.5 gal water per cubic foot of material with 18 percent solids yields a slurry of about 11 percent solids content. This resulting slurry is still too thick for irrigation without additional dilution. It could, however, be spread from a honeywagon.

Spreading by Honeywagon

Assume a honeywagon capacity of 1,500 gal and round-trip time of 30 min to fill, spread, and return. From figure 11-1, the time required to spread 1 acre-ft (43,560 ft^3) is about 36 hours for 10-min round trips or 108 hours for 30-min round trips. The time required to empty 3.2 acre-ft of storage is:

$$3.2 \times 108 = 346 \text{ hr} = \text{a little more than 43 8-hour days}$$

Spreading by Use of Big Gun

Spreading by use of big-gun equipment requires further dilution of the slurry to about 7 percent solids. From figure 11-3, about 11.5 gal water is required per cubic foot of material with 18 percent solids. Runoff was computed to add 4.5 gal water per cubic foot of manure. Therefore, 11.5 - 4.5 = 7.0 gal additional dilution water needed per cubic foot of manure. Additional dilution water required is:

$$7.0 \text{ gal/ft}^3 \times 87{,}600 \text{ ft}^3 = 613{,}000 \text{ gal}$$

$$\frac{613{,}000 \text{ gal}}{7.48 \text{ gal/ft}^3} = 82{,}000 \text{ ft}^3 \text{ or } 1.9 \text{ acre-ft}$$

Total liquid to be spread:

$$\begin{aligned} \text{Runoff} &= 1.2 \text{ acre-ft} \\ \text{Manure} &= 2.0 \text{ acre-ft} \\ \text{Dilution} &= \underline{1.9} \text{ acre-ft} \\ \text{Total} &= 5.1 \text{ acre-ft or } 61.2 \text{ acre-in} \end{aligned}$$

SPRAY APPLICATION LAYOUT

Previous computations indicated that approximately 42 acres are needed. Use 40 acres.

$$\text{Volume of application} = \frac{61.2 \text{ acre-in}}{40 \text{ acre}} = 1.5 \text{ in/acre}$$

Assume a square field 1,320 ft x 1,320 ft. Select a self-propelled big gun using 660 ft of 4-in flexible hose. Assume 2,000 ft of 6-in polyvinyl chloride (PVC) pipe from storage reservoir to most remote connection. Assume that a Nelson Big Gun P200T, Taper Bore, with 1.05-in nozzle is selected. Based on manufacturer's data (table 11-1) this gun applies 310 gal/min at 90 lb/in^2 and has a wetted diameter of 390 ft. Spacing should be from 75 to 80 percent of the wetted diameter or 292 to 312 ft. One acre-in per hour equals about 450 gal/min, so with an application rate of 310 gal/min:

$$\frac{310}{450} = 0.7 \text{ acre-in/hr}$$

Thus, the time required to apply 61.2 acre-in is $\frac{61.2}{0.7}$ or 87 hours.

Table 11-1.--Nozzle performance (Courtesy L. R. Nelson Mfg. Co.)

Models F200T & P200T Performance (Taper Bore Nozzle) 27° Trajectory*

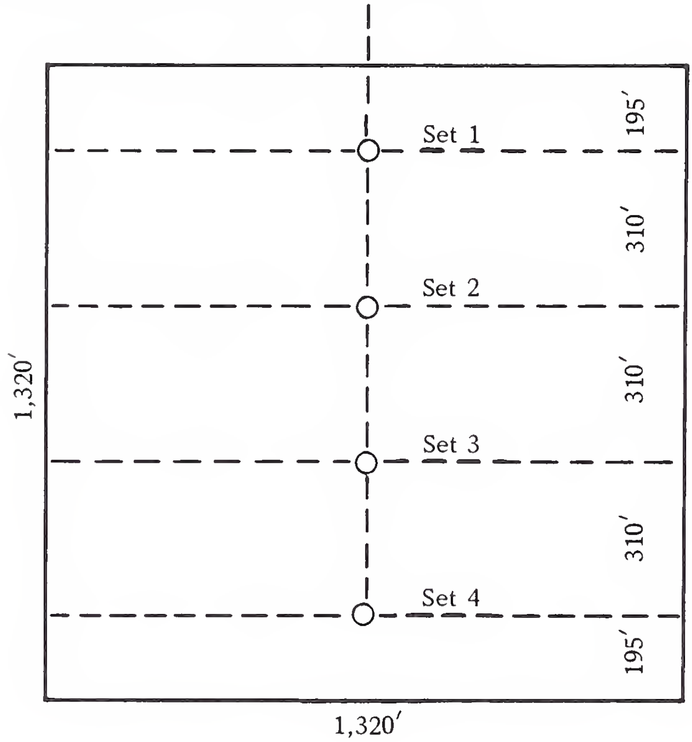
P.S.I.	NOZZLE 1.05" GPM	DIA.	NOZZLE 1.2" GPM	DIA.	NOZZLE 1.3" GPM	DIA.	NOZZLE 1.4" GPM	DIA.	NOZZLE 1.5" GPM	DIA.	NOZZLE 1.6" GPM	DIA.	NOZZLE 1.75" GPM	DIA.
80	290	380'	380	410'	445	430'	515	450'	590	470'				
90	310	390'	405	425'	475	445'	545	465'	625	485'	715	505'	855	535'
100	325	400'	425	440'	500	460'	575	480'	660	500'	755	520'	900	550'
110	340	410'	445	450'	525	470'	605	495'	695	515'	790	535'	945	565'
120	355	420'	465	460'	545	480'	630	505'	725	530'	825	550'	985	580'
130	370	425'	485	465'	565	485'	655	515'	755	540'	860	560'	1025	590'

Models F200R & P200R Performance (Ring Nozzle) 27° Trajectory*

P.S.I.	Nominal 1¼" (actual 1.29") GPM	DIA.	Nominal 1⅜" (actual 1.46") GPM	DIA.	Nominal 1½" (actual 1.56") GPM	DIA.	Nominal 1⅝" (actual 1.66") GPM	DIA.	Nominal 1¾" (actual 1.74") GPM	DIA.	Nominal 1⅞" (actual 1.83") GPM	DIA.	Nominal 2" (actual 1.93") GPM	DIA.
80	290	370'	380	400'	445	420'	515	440'	590	455'				
90	310	380'	405	415'	475	435'	545	455'	625	470'	715	485'	855	505'
100	325	390'	425	425'	500	445'	575	465'	660	480'	755	500'	900	520'
110	340	400'	445	435'	525	455'	605	475'	695	490'	790	510'	945	535'
120	355	410'	465	445'	545	465'	630	485'	725	500'	825	520'	985	545'
130	370	415'	485	450'	565	470'	655	490'	755	505'	860	525'	1025	550'

*The diameter of throw is about 5% less on the 21° model than on the 27° model.

Divide the field into four sets as follows:



To cover the field in four sets in 87 hours, use 22 hours per set.

$$\text{Travel speed} = \frac{1,320}{22} = 60 \text{ ft/hr}$$

For a wetted diameter of 390 ft and a discharge rate of 310 gal/min, figure 11-4 shows an application rate of 0.26 in/hr for full-circle application. For seven-eighths-circle application, the application rate is:

$$8/7 \times 0.26 = 0.30 \text{ in/hr}$$

Computation of friction losses is according to tables 11-2 and 11-3, which are examples of typical design data provided by manufacturers. From table 11-3, friction loss for 6-in PVC pipe, 310 gal/min, is 0.65 ft/100 ft. Loss for 2,000 ft is 13.5 ft. From table 11-2, loss for 660 ft of 4-in flexible hose, 310 gal/min, is 9.5 lb/in^2 or 21.9 ft. Total friction loss for water is 13.5 + 21.9 = 35.4. Add 10 percent for difference in viscosity between waste and water, i.e., 3.5 ft.

Total friction loss for waste	=	39 ft
Assume elevation difference	=	28 ft
Pressure at nozzle, 90 lb/in^2	=	208 ft
Total head required at pump	=	275 ft

Select pump from manufacturer's data to pump 310 gal/min against a head of 275 feet.

Table 11-2.--Estimated pressure loss in pounds per square inch for Nelson mobile-pipe when operating at about 100 pounds per square inch [1/]

Gallons per minute	Nominal inside diameter: 2-1/2 in, Length 100 ft	2-1/2 in, 660 ft	3 in, 100 ft	3 in, 660 ft	4 in, 100 ft	4 in, 660 ft	5 in, 100 ft	5 in, 660 ft
	lb/in^2		lb/in^2		lb/in^2		lb/in^2	
100	1.6	10.6	---	---	---	---	---	---
150	3.4	22.4	1.4	9.3	---	---	---	---
200	5.6	37.0	2.4	15.8	---	---	---	---
250	---	---	3.6	23.8	0.95	6.3	---	---
300	---	---	5.1	33.6	1.35	8.9	---	---
400	---	---	---	---	2.3	15.2	---	---
500	---	---	---	---	3.5	23.1	1.1	7.3
600	---	---	---	---	4.9	32.4	1.6	10.6
700	---	---	---	---	---	---	2.1	13.9
800	---	---	---	---	---	---	2.7	17.8
900	---	---	---	---	---	---	3.4	22.4
1,000	---	---	---	---	---	---	4.2	27.7

[1/] Courtesy L. R. Nelson Mfg. Co.

Table 11-3.--Friction Head Loss in Plastic Irrigation Pipelines Manufactured of PVC or ABS Compounds Standard Dimenstion Ratio - SDR = 21[1/]

For IPS Pipe

Friction Head Loss in Feet per Hundred Feet

Q Gallons per min.	4-inch 4.072 ID	5-inch 5.033 ID	6-inch 5.993 ID	8-inch 7.805 ID	10-inch 9.728 ID	Q Gallons per min.
75	.31	.11				75
80	.35	.12	.05			80
85	.39	.14	.05			85
90	.43	.15	.06			90
95	.48	.17	.07			95
100	.52	.19	.07			100
110	.63	.22	.09			110
120	.74	.26	.10			120
130	.85	.30	.12			130
140	.98	.35	.14			140
150	1.11	.40	.16	.05		150
160	1.26	.44	.19	.05		160
170	1.41	.49	.21	.06		170
180	1.57	.55	.24	.07		180
190	1.73	.61	.26	.07		190
200	1.90	.67	.29	.08		200
220	2.28	.81	.34	.09		220
240	2.67	.95	.40	.10		240
260	3.10	1.10	.46	.12		260
280	3.56	1.26	.54	.14	.05	280
300	4.04	1.43	.61	.17	.05	300
320	4.56	1.62	.69	.19	.06	320
340	5.10	1.82	.77	.21	.07	340
360	5.67	2.02	.86	.24	.08	360
380	6.26	2.22	.95	.26	.09	380
400	6.90	2.45	1.04	.28	.10	400
420		2.69	1.14	.31	.10	420
440		2.92	1.25	.34	.11	440
460		3.18	1.35	.37	.12	460
480		3.44	1.46	.41	.14	480
500		3.70	1.58	.43	.15	500
550		4.42	1.89	.52	.18	550
600		5.21	2.22	.61	.21	600
650		6.04	2.58	.71	.24	650
700		6.92	2.96	.81	.28	700
750			3.36	.93	.32	750
800			3.78	1.04	.36	800
900			4.71	1.30	.44	900
1000			5.73	1.58	.54	1000

1/SDR No.	Factor
13.5	1.35
17	1.13
21	1.00
26	.91
32.5	.84
41	.785
51	.75

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 12. WASTE MANAGEMENT SYSTEM COMPONENTS

Overall coordination by R. C. Barnes, Jr., assistant director, Engineering Division, SCS, Washington, D.C.

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Compiled by Joseph H. Harrington, Jr., state conservation engineer, SCS, Columbus, Ohio.

PART III - DEBRIS BASINS (Settling Facilities)

Compiled by William F. Long, water management engineer (ret.), SCS, Portland, Oreg.

PART IV - DISPOSAL LAGOONS

Compiled by Glenn E. Stucky, water management engineer, SCS, Broomall, Pa.

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PART V - CONSERVATION PRACTICES FOR WASTE MANAGEMENT

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PART VI - HOLDING PONDS

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SCS, Fort Worth, Tex.

PART VII - IRRIGATION SYSTEMS

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PART VIII - POND SEALING OR LINING

Compiled by Stanley N. Hobson, state conservation engineer, SCS, Spokane, Wash.

Figures

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CHAPTER 12. WASTE MANAGEMENT SYSTEM COMPONENTS

PART I - GENERAL

Most agricultural operations produce waste in one form or another. Although much of this waste is assimilated naturally, confined operations can produce concentrated waste in quantities that require especially planned and designed waste management systems. Agricultural wastes, properly utilized, can be considered natural resources that produce economic returns.

Agricultural waste management systems properly planned, designed, and installed prevent or minimize degradation of air, soil, and water resources and protect public health and safety.

The goal of SCS should be systems that prevent discharge of pollutants to surface or ground water and that recycle waste through soil and plants to the fullest extent possible. Such systems include those for disposal of livestock and poultry wastes, effluents and sludges from municipal waste treatment plants, and agricultural processing wastes.

Planning and designing waste management systems that function properly require an interdisciplinary approach. The training and experience of soil scientists, geologists, engineers, plant scientists, and biologists should be used to the fullest extent possible.

Individual conservation practices are the building blocks or components that can be put together in proper combination for a management system for a given site condition. Such components include existing practices listed in the National Handbook of Conservation Practices, adaptations thereof, and other measures necessary for collecting, storing, treating, distributing, utilizing, or disposing of wastes safely. Complete systems also include the required conservation treatment and management of disposal areas.

This chapter supplements published conservation standards. It provides details of planning, design, installation, operation, maintenance, and management of the individual practices included in overall waste management systems. It includes aids, tables, graphs, and procedures useful in planning and designing systems.

This chapter can be further supplemented at regional, state, and area levels with locally adapted aids and information that have been officially approved for use.

PART II - AGRICULTURAL WASTE STORAGE FACILITIES

1. GENERAL

DEFINITION

An agricultural waste storage facility is an individually designed fabricated structure for temporary storage of animal or other agricultural waste.

INTRODUCTION

The temporary storage of agricultural waste is one of the oldest practices in the history of agriculture. The manure pile behind the barn was as accepted as were the animals themselves, and it often was moved to the field for disposal only after it became a nuisance. Changing agricultural operations and increasing concern for environmental quality have now created a need for incorporating waste storage facilities in overall waste management plans. Confinement units are larger, resulting in larger amounts of waste produced daily. The public now recognizes that agricultural wastes are potential pollutants and that they must be kept from polluting surface- and ground-water resources.

Because of its nutrient value, manure should be considered a resource rather than a waste and, when possible, use of any waste as fertilizer should be evaluated and incorporated into an owner's management plan.

Table 12-1.--Approximate fertilizer value of manure[1/]

Animal	Nutrients in manure		
	Nitrogen	Phosphorus	Potassium
	lb/ton	lb/ton	lb/ton
Dairy cattle	11	2	10
Beef cattle	14	4	9
Swine	10	3	8
Horses	14	2	12
Sheep	28	4	20
Poultry	31	8	7

[1/] Values from Midwest Plan Service Publication AED-8. Handling liquid manure. Ames, Iowa. 1966.

MANURE PRODUCTION

Among the factors that affect livestock manure production are climate, type of feed, and livestock production methods. Table 12-2 or data in chapter 4 can be used for estimating manure production if good local records are not available.

Table 12-2.--Approximate daily production of manure[1/]

Animal	Solids and liquids	Water
	ft^3/day	Percent
Dairy cattle (1,000 lb).......	1.4	80-90
Beef cattle (1,000 lb)........	1.0	80-90
Horses (1,000 lb).............	.9	65
Swine (1,000 lb)..............	1.0	75
Swine (sow with litter).......	.55	75
Sheep (1,000 lb)..............	.7	70
Poultry (1,000 lb)............	1.0	55-75

[1/]A generally accepted conversion value is 1 ton of manure equals 32 to 34 ft^3.

2. DESIGN

Agricultural waste storage facilities include liquid-manure tanks, manure stacking facilities, and earth storage facilities.

Liquid-manure tanks are made of reinforced concrete, reinforced concrete block, or other durable material for storing manure, milking parlor waste, flushing water, and, in some cases, runoff. These tanks are usually constructed below ground but aboveground installations such as reinforced concrete silos have been used successfully.

Manure stacking facilities are constructed for storing wastes in solid or semisolid form. The kind of facility depends on the stacking properties of the manure. In humid areas it may be necessary to roof the facility, depress the storage area and build a ramp for unloading, or build a fourth wall with flashboards across the access opening to keep saturated manure from flowing out of the storage.

Earth storage facilities are holding areas with earth walls and floors. They can be used only in areas of impervious soils and where a seasonal high water table will not cause problems. These facilities differ from holding ponds in that they store slurry or solid animal waste rather than runoff.

LIQUID-MANURE TANKS

Location

The tank must be located as near the source of waste as practical. Access, cleaning, unloading and location of other facilities must be considered. For large areas such as free-stall dairy barns, it may be desirable to locate two or more tanks within the facility in order to reduce the scraping distance to the tank.

The possibility of pollution and objectionable odor must also be considered in selecting the tank site. Strong odors are released from liquid manure tanks, especially during agitation before pumpout, and

the distance to neighboring residences and highways and direction of prevailing winds must be taken into account.

Certain locations present special design problems. Often, however, another site (or location) is available, and the extra costs for a special design can be avoided. Some examples of problem locations are soils in which seepage would be excessive, differential consolidation of the foundation, and the presence of bedrock near the surface.

All local health regulations must be considered. The distance to wells or other domestic water supplies, distance to the milking parlor, requirements for vector control, and requirements for ventilation if the tank is located within an enclosed building need to be considered.

Soils and Foundation

A thorough soils investigation should be made to determine the nature of the foundation on which the tank is to be constructed. Borings or test pits should be made at intervals to determine the nature of the soil. The number of borings or test pits needed depends on any significant changes in the soil. The investigation should be made to depths sufficient to identify underlying materials that may affect the design or safety of the structure.

Size

The factors that need to be considered in determining the size of a liquid-manure tank are:

1. Number, kind, and average weight of livestock
2. Design detention time
3. Amount of surface runoff
4. Amount of flushing water
5. Amount of wash water from milking parlor or milkhouse
6. Amount of water for initially charging the tank

Before determining the size of tank, an owner should consider any plan he has to enlarge his livestock herd that would result in overtaxing a facility designed for his present needs. If he does not have good records on manure production for his operation or if records are not available for a similar operation, tables 4-1, 9-1, or 12-2 or production figures included in the engineering practice standard can be used for estimating manure production.

Design detention time is controlled by climatic conditions or by the owner's management plan. Usually, in northern areas climate is the controlling factor since land disposal is not possible during much of winter and spring. The cropping pattern on some farms may control the detention time if no land is available for manure disposal during the growing season.

Example 1

Determine the volume and surface area required for a liquid manure tank 10 feet deep for a 150-cow dairy.

Given: Average weight of cows, 1,400 lb; waste from milking parlor, 350 gal/day; no storm runoff; detention time, 90 days because ground is wet January through March.

Solution:

$$\text{Volume of manure} = \frac{\text{ft}^3/1{,}000\ \text{lb/day} \times \text{No. livestock} \times \text{av. wt.} \times \text{days of detention}}{1{,}000}$$

$$= \frac{1.4 \times 150 \times 1{,}400 \times 90}{1{,}000}$$

$$= 26{,}450\ \text{ft}^3$$

$$\text{Milking parlor waste} = \frac{\text{gal/day} \times \text{days of detention}}{7.5\ \text{gal/ft}^3}$$

$$= \frac{350 \times 90}{7.5}$$

$$= 4{,}200\ \text{ft}^3$$

$$\text{Total volume of wastes} = 26{,}450\ \text{ft}^3 + 4{,}200\ \text{ft}^3 = 30{,}650\ \text{ft}^3$$

Effective depth = total depth - depth of water for initial charging (1 ft)

$$= 10\ \text{ft} - 1\ \text{ft} = 9\ \text{ft}$$

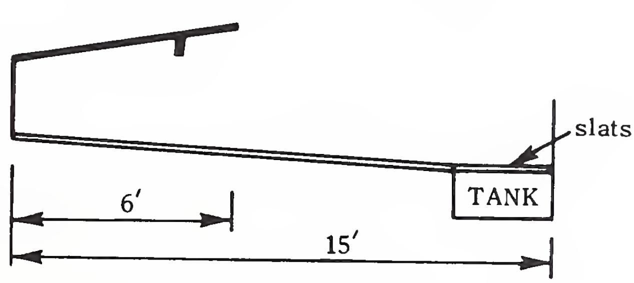
$$\text{Surface area} = 30{,}650\ \text{ft}^3 \div 9\ \text{ft} = \underline{3{,}410\ \text{ft}^2}$$

$$\text{Total volume of tank} = 3{,}410\ \text{ft}^2 \times 10\ \text{ft} = \underline{34{,}100\ \text{ft}^3}$$

Example 2

Determine the volume and width required for a manure tank 6 ft deep for a swine finishing unit consisting of 10 pens, 10 ft x 15 ft, 20 hogs per pen.

Given: Average weight of hogs is 150 lb; for each pen: 6 ft is roofed and drained away from facility, 9 ft is exposed to storm runoff that will drain into tank; flushing water averages 80 gal/day; detention time is 60 days; maximum average 2-month rainfall is 6.5 in.; initial charge is 1 ft deep.



Solution:

$$\text{Volume of manure} = \frac{\text{ft}^3/1{,}000 \text{ lb/day x No. swine x av. wt. x days of detention}}{1{,}000}$$

$$= \frac{1.0 \times 200 \times 150 \times 60}{1{,}000} = 1{,}800 \text{ ft}^3$$

$$\text{Volume of wash water} = \frac{\text{gal/day x days of detention}}{7.5 \text{ gal/ft}^3}$$

$$= \frac{80 \times 60}{7.5} = 640 \text{ ft}^3$$

$$\text{Runoff} = \frac{\text{av. in. rainfall x exposed area}}{12}$$

$$= \frac{6.5 \times 9 \times 100}{12} = 487 \text{ ft}^3$$

$$\text{Total waste and runoff} = 1{,}800 + 640 + 487 = 2{,}927 \text{ ft}^3$$

$$\text{Width} = \frac{\text{vol. waste and runoff}}{\text{length x effective depth}} = \frac{2{,}927}{100 \times (6-1)} = \frac{5.8 \text{ ft}}{\underline{\text{Use 6 ft}}}$$

$$\text{Total volume of tank} = 6 \times 6 \times 100 = \underline{3{,}600 \text{ ft}^3}$$

Structural Considerations

Holding tanks should be constructed of reinforced concrete, reinforced concrete block, or other suitable durable material. The tanks must be sufficiently watertight to hold liquids within the tank. In areas of seasonal high water tables it is necessary to prevent ground water seepage into the tank and to relieve hydrostatic pressure by installing a drainage system or using a special design.

The tank roof provides lateral support for the sidewalls and supports livestock or equipment. Several standard roof designs are available. It is important to use a design that has enough strength for the intended loading. Pump openings and loading slots in the tank roof must be located so as not to affect the integrity of the roof design. The number and the location of slot openings usually are established for the convenience of the owner's operations. Pump openings should be spaced at frequent intervals along the tank to allow for sufficient agitation of the manure before pumpout. The recommended maximum spacing between pump openings is 30 feet. Tight-fitting covers should be

provided for all openings, and the openings should be closed when not in use.

Covered tanks within enclosed buildings should be properly vented to remove noxious gases. Ventilation within buildings, especially those with tanks having slatted floors, must be carefully designed to protect the health of both livestock and human beings.

Emptying the Tank

During the storage period manure solids tend to settle on or near the bottom of the tank, and it is usually necessary to agitate the mixture just before removal.

Agitation of liquid manure can release noxious gases such as methane (CH_4), hydrogen sulfide (H_2S), ammonia (NH_3), and carbon dioxide (CO_2), which can be fatal to both animals and human beings. Special care must be taken to provide adequate ventilation during agitation. If there is a question regarding the adequacy of ventilation, it is recommended that the animals be evacuated from the building and that the operator wear an oxygen mask.

Operators for their safety should (1) avoid working alone during agitation or pumpout and (2) never enter an empty tank that has contained liquid manure because gases may remain inside the tank.

Standard Drawings

Several standard drawings used in the field are illustrated in figures 12-1 through 12-5. Midwest Plan Service Plan #74303 is also used extensively as is the SCS Standard Watertight Reinforced Concrete Waste Holding Tank Plan. All should be designed to meet current SCS criteria.

MANURE STACKING FACILITY

Location

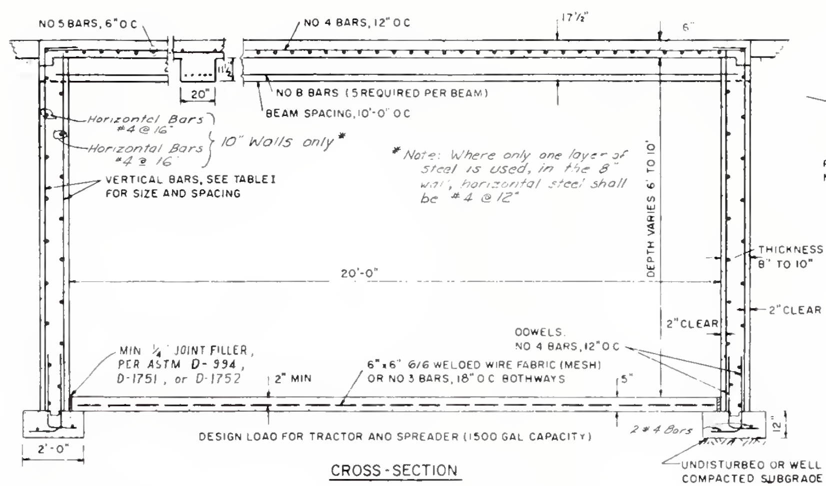
The manure stacking facility should be located as near the source of waste as practical with due consideration given to access, other facilities, and unloading. The location must allow for diverting runoff from the feedlot, roofs, and other surfaces away from the facility and for collecting or otherwise disposing of all leakage before it can reach a natural watercourse.

Although odor from manure stacking facilities is generally not so strong as that from liquid manure tanks, proximity to neighboring residences should still be considered.

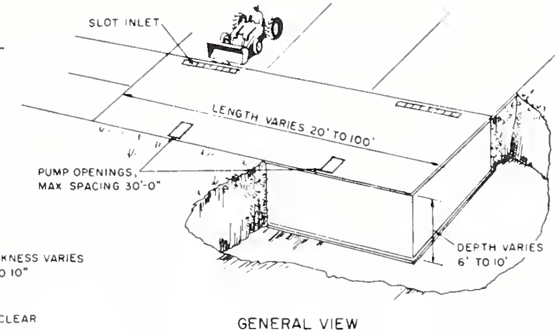
All local health regulations must be considered in locating the facility.

Size

The number, type, and average weight of animals, amount of bedding, and design detention time need to be considered in determining the size of the stacking facility. Procedures for determining the volume of



CROSS-SECTION



GENERAL VIEW

TABLE I - WALL THICKNESS AND VERTICAL REINFORCEMENT

HEIGHT FT	THICKNESS, IN	REINFORCEMENT SIZE & SPACING	REMARKS
6	8	NO 5 @ 9" O C	SINGLE CURTAIN ON WALL CENTERLINE
8	10	NO. 4 @ 12" OUTSIDE NO 5 @ 10" INSIDE	DOUBLE CURTAIN SEE DETAIL
10	10	NO 5 @ 9" OUTSIDE NO 5 @ 7" INSIDE	DOUBLE CURTAIN SEE DETAIL

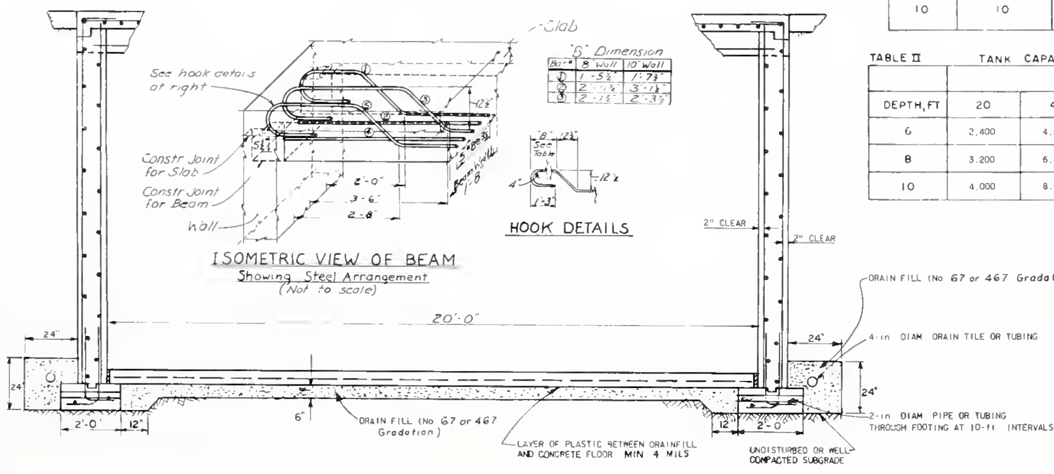
TABLE II TANK CAPACITIES IN CU FT. - 20 FT INSIDE WIDTH

	LENGTH, FT				
DEPTH, FT	20	40	60	80	100
6	2,400	4,800	7,200	9,600	12,000
8	3,200	6,400	9,600	12,800	16,000
10	4,000	8,000	12,000	16,000	20,000

DRAIN FILL GRADATION (No 67)

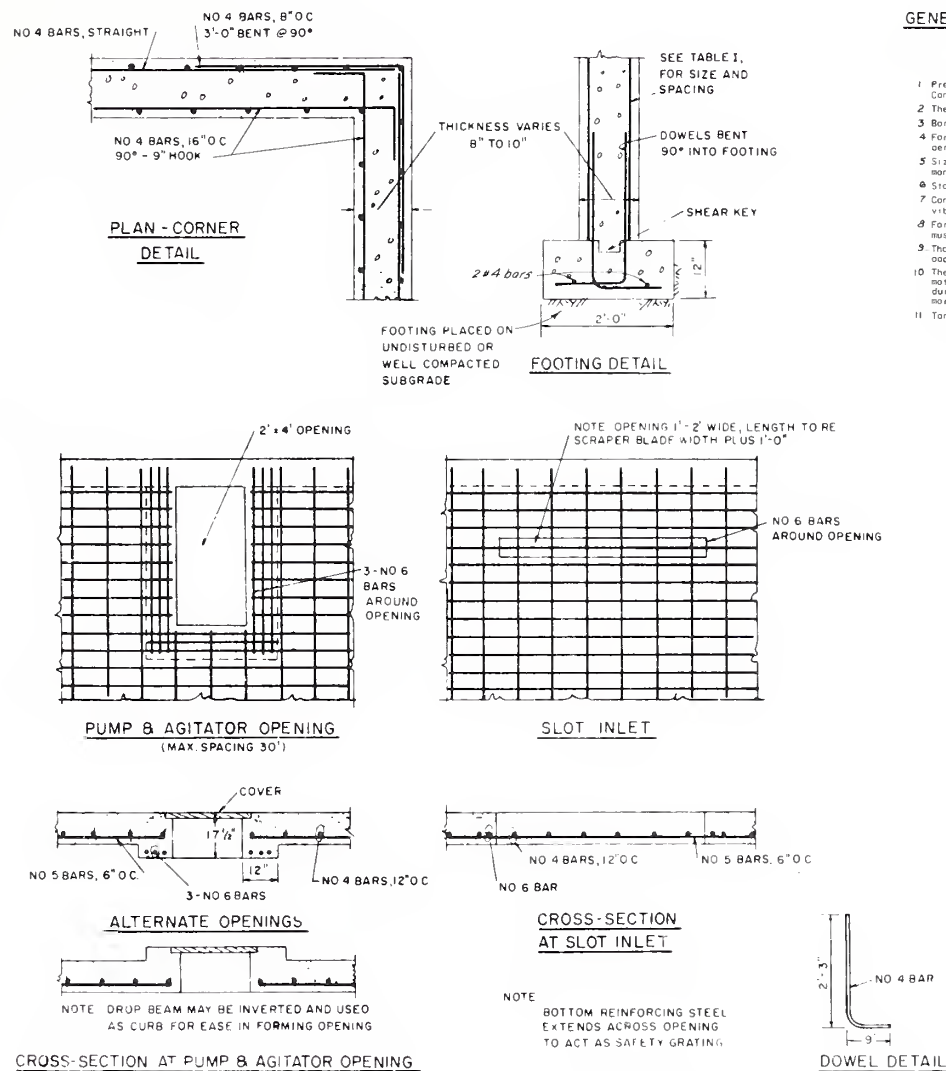
Size	% Passing
1"	100%
¾"	90-100%
⅜"	20-55%
No 4	0-10%
No 8	0-5%

No 647 may also be used



DRAIN FILL DETAILS

Figure 12-1(a).--Reinforced concrete; walls with footings: solid roof; length (inside) 20' to 100' by 10' increments; width (inside) 20' maximum; depth (inside) 6', 8', 10'.



GENERAL NOTES

1. Precast plank or double tee beams may be used as an alternate roof system. Consult the appropriate manufacturers for details.
2. The tank cover shall be installed before the walls are backfilled.
3. Barn cleaner or gutter inlet may be adapted to the system.
4. Forms shall be tight, straight, and well braced. Forms should be oiled to permit easy removal.
5. Size and shape of pump, agitator, and fill openings may vary. Consult equipment manufacturer for details.
6. Standard manufactured wall forms may be used in wall construction.
7. Concrete must be evenly distributed in the forms and spaded or mechanically vibrated to assure consolidation.
8. Forms for cast-in-place tank cover must be adequately shored. Shoring and forms must be removed through pump and agitator opening.
9. The area surrounding the tank shall be paved (minimum width 10 feet), or paved approach ramps built.
10. The excavation along the outside of the walls shall be backfilled with selected material in horizontal layers not exceeding two feet in thickness. At no time during backfilling shall the surface elevation of the backfill material vary by more than two feet.
11. Tanks shall be properly vented to prevent the accumulation of toxic gases.

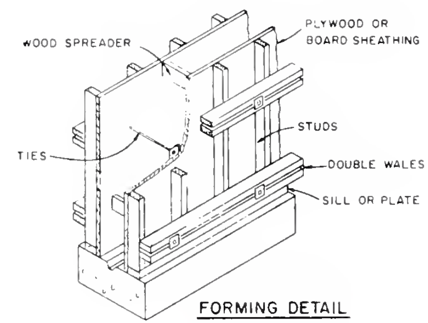
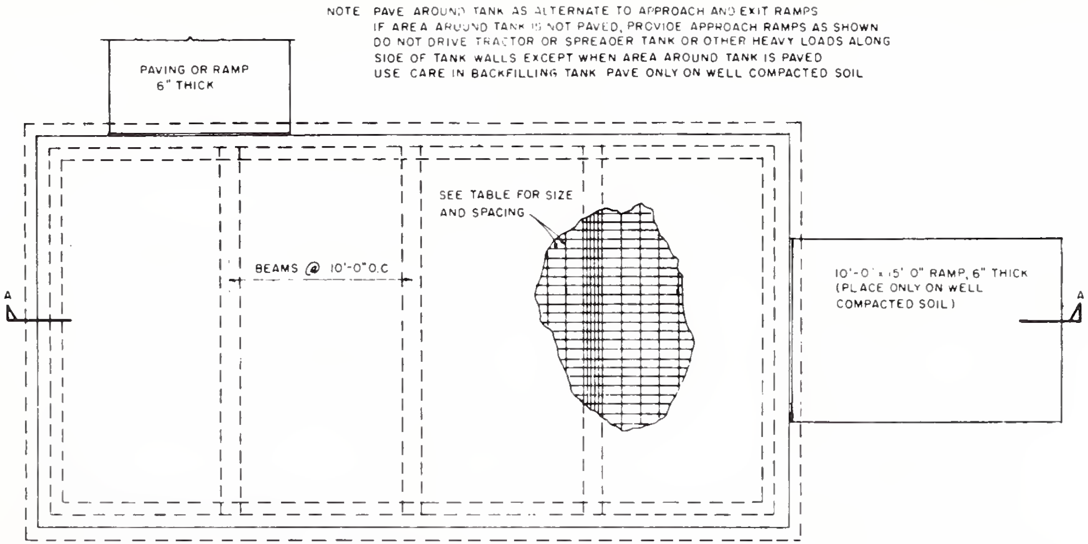
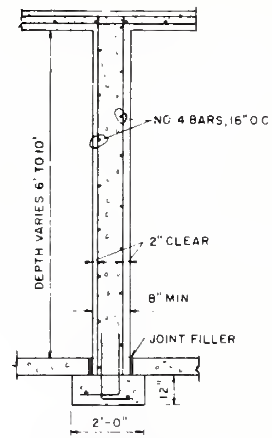


Figure 12-1(b)

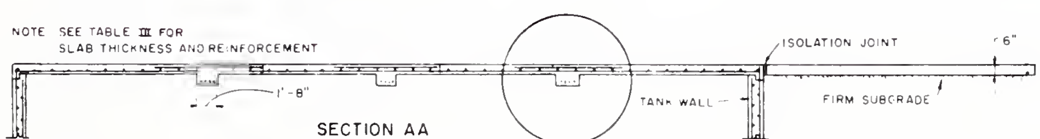


PLAN VIEW
TANK AND RAMP

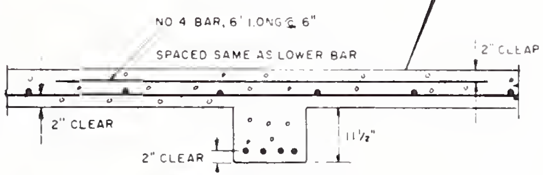


CROSS - SECTION
PARTITION WALL
(OPTIONAL)

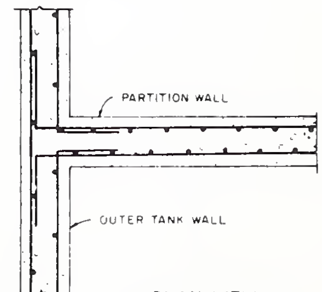
NOTE SEE TABLE III FOR
SLAB THICKNESS AND REINFORCEMENT



SECTION AA



BEAM & SLAB DETAIL



PLAN VIEW
PARTITION WALL

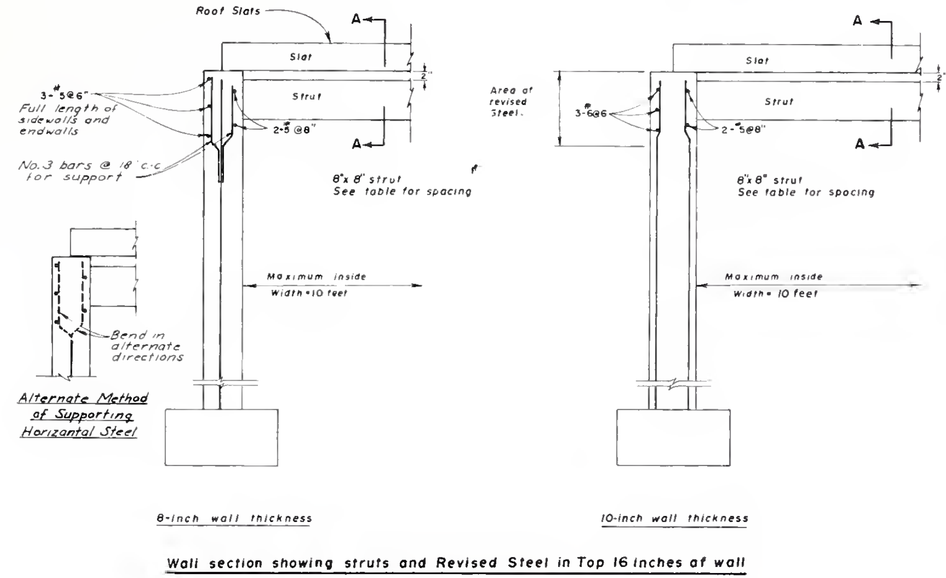
TABLE-IV - VERTICAL REINFORCEMENT FOR PARTITION WALL

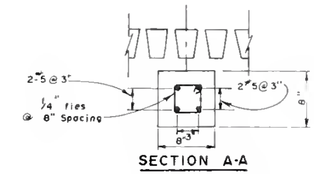
HEIGHT, FT	THICKNESS, IN	REINFORCEMENT REQUIRED (EACH CURTAIN)
6	8	NO 4 BARS, 12" O C
8	8	NO. 4 BARS, 12" O.C
10	10	NO 5 BARS, 9" O.C

TABLE III - THICKNESS AND REINFORCEMENT REQUIRED FOR BEAM AND SLAB COVER

BEAM SIZE INCLUDING SLAB	REINFORCEMENT REQUIRED IN BEAM	SLAB THICKNESS	SLAB REINFORCEMENT PERPENDICULAR TO BEAMS	SLAB REINFORCEMENT PARALLEL TO BEAMS
20" x 17½"	5 - NO 8 BARS	6"	NO 5 BARS, 6" OC	NO 4 BARS, 12" OC

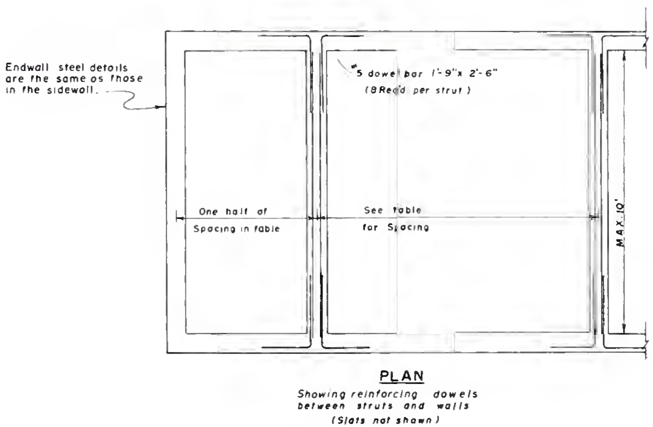
Figure 12-1(c)





SPACING FOR WALL STRUTS

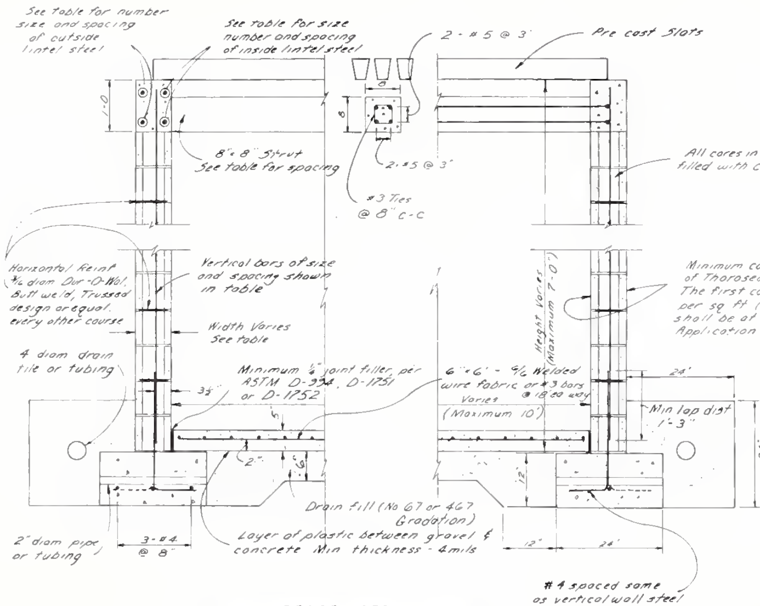
HEIGHT FT.	WALL THICKNESS IN	STRUT SPACING
6'	8"	10'
7'	10"	12'
8'	10"	11'
9'	10"	10'
10'	10"	9'



Notes
1. When slotted type roof is used, widths are limited to 10 feet.
2. When slotted type roof is used, any roof details shown on sheets 1 and 2 do not apply.
3. When slotted roof is used this sheet shall be substituted for sheet 3

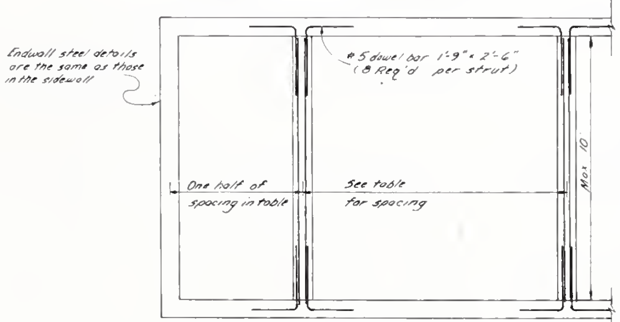
Not to Scale

Figure 12-2.--Reinforced concrete; walls with footings: slatted roof; length (inside) 20' to 100' by 10' increments; width (inside) 10'; depth (inside) 6', 7', 8', 9', 10'. NOTE: Use figures 12-1(b) and (c) also with figure 12-2.



CROSS SECTION

(Symmetrical about vertical ℄ Details shown only on one side apply to both sides.)



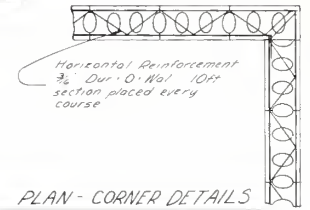
PLAN

Showing reinforcing of struts (Slots not shown)

DRAIN FILL - NO 67 GRADATION

SIZE	% PASSING
1"	100
¾"	90 - 100
⅜"	20 - 55
No 4	0 - 10
No 8	0 - 5

No 467 may also be used



PLAN - CORNER DETAILS

Class I loading shall be assumed where coarse-grained soil backfill material, such as No 8 drain fill, is used
Class II loading shall be assumed where fine grained soil backfill material is used

HORIZONTAL STEEL IN LINTEL

Ht (ft)	Inside Class I Loading 8" wall	10" wall	12" wall	Inside Class II Loading 8" wall	10" wall	12" wall	Outside Class I Loading 8" wall	10" wall	12" wall	Outside Class II Loading 8" wall	10" wall	12" wall
4	2#4@8	2#5@8	2#5@8	2#4@8	2#5@8	2#5@8	2#6@8	2#7@8	2#7@8	2#6@8	2#7@8	2#7@8
	3#3@4	3#4@4	3#4@4	3#3@4	3#4@4	3#4@4	3#5@4	3#6@4	3#6@4	3#5@4	3#5@4	3#6@4
4½	2#4@8	2#5@8	2#5@8	2#4@8	2#5@8	2#5@8	2#6@8	2#7@8	2#7@8	2#6@8	2#7@8	2#7@8
	3#3@4	3#4@4	3#4@4	3#3@4	3#4@4	3#4@4	3#5@4	3#6@4	3#6@4	3#5@4	3#5@4	3#6@4
5	2#4@8	2#5@8	2#5@8	2#4@8	2#5@8	2#5@8	2#6@8	2#7@8	2#7@8	2#6@8	2#7@8	2#7@8
	3#3@4	3#4@4	3#4@4	3#3@4	3#4@4	3#4@4	3#5@4	3#5@4	3#6@4	3#5@4	3#5@4	3#6@4
5½	2#4@8	2#5@8	2#5@8	2#4@8	2#5@8	2#5@8	2#6@8	2#7@8	2#7@8	2#6@8	2#7@8	2#7@8
	3#3@4	3#4@4	3#4@4	3#3@4	3#4@4	3#4@4	3#5@4	3#5@4	3#6@4	3#5@4	3#5@4	3#6@4
6	2#4@8	2#5@8	2#5@8	—	2#5@8	2#5@8	2#6@8	2#7@8	2#7@8	—	2#7@8	2#7@8
	3#3@4	3#4@4	3#4@4	—	3#4@4	3#4@4	3#5@4	3#5@4	3#6@4	—	3#6@4	3#6@4
6½	2#4@8	2#5@8	2#5@8	—	2#5@8	2#5@8	2#6@8	2#7@8	2#7@8	—	2#7@8	2#7@8
	3#3@4	3#4@4	3#4@4	—	3#4@4	3#4@4	3#5@4	3#6@4	3#6@4	—	3#5@4	3#6@4
7	—	2#5@8	2#5@8	—	2#5@8	2#5@8	—	2#7@8	2#7@8	—	2#7@8	2#7@8
	—	3#4@4	3#4@4	—	3#4@4	3#4@4	—	3#5@4	3#6@4	—	3#5@4	3#6@4

STRUT SPACING

Ht (ft)	Class I Loading 8" wall	10" wall	12" wall	Class II Loading 8" wall	10" wall	12" wall
4	12.5'	17.5'	22.0'	11.0'	15.0'	19.0'
4½	11.5'	16.0'	20.0'	10.0'	13.5'	17.5'
5	10.5'	14.5'	18.5'	9.0'	12.5'	16.0'
5½	9.5'	13.5'	17.0'	8.5'	11.5'	14.5'
6	9.0'	12.5'	16.0'	—	11.0'	13.5'
6½	8.5'	12.0'	15.0'	—	10.0'	13.0'
7	—	11.0'	14.0'	—	9.5'	12.0'

VERTICAL WALL STEEL

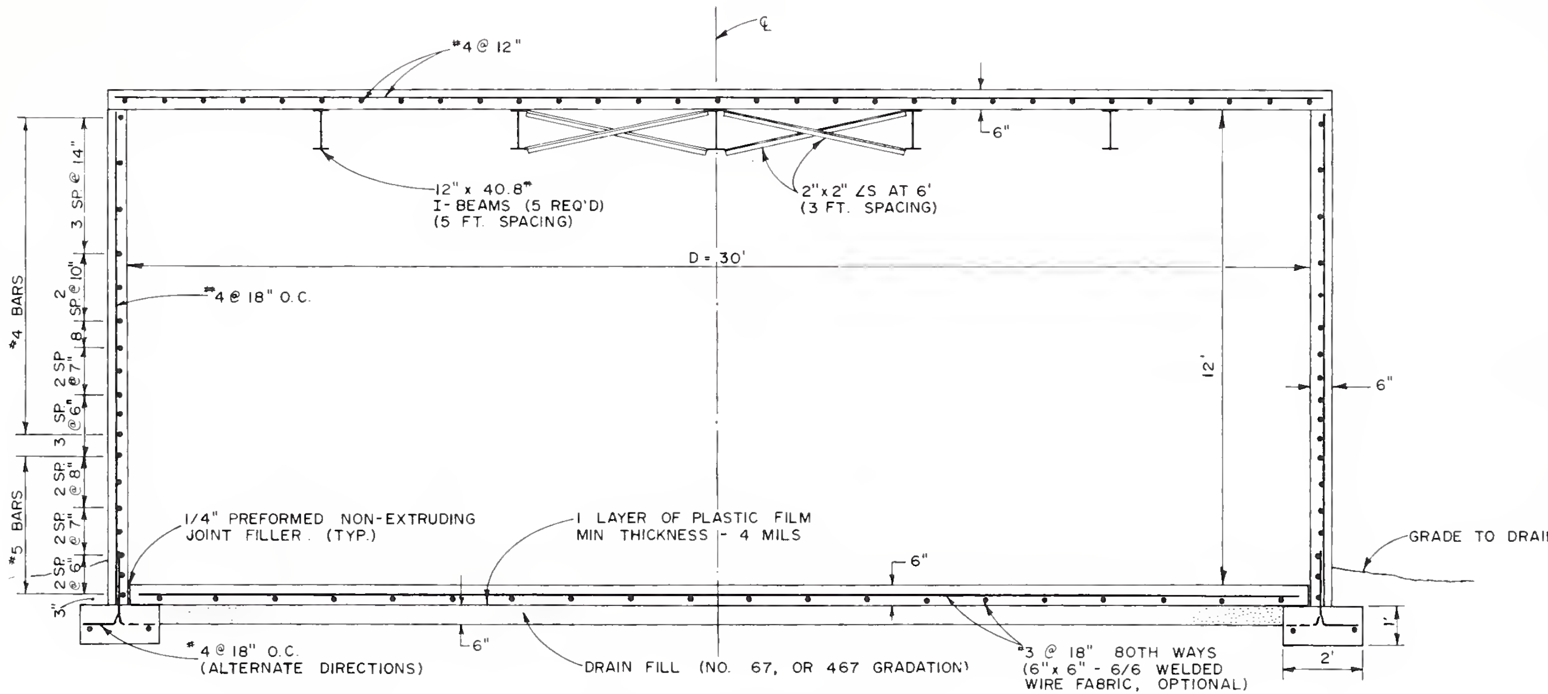
Ht (ft)	Class I Loading 8" wall	10" wall	12" wall	Class II Loading 8" wall	10" wall	12" wall
4	#4@16	#4@16	#4@16	#4@16	#4@16	#4@16
	—	—	—	—	—	—
4½	#4@16	#4@16	#4@16	#5@16	#4@16	#4@16
	—	—	—	—	—	—
5	#4@8	#4@16	#4@16	#6@16	#4@16	#4@16
	#5@16	—	—	#4@8	—	—
5½	#4@8	#4@16	#4@16	#7@16	#4@8	#4@16
	#5@16	—	—	#5@8	#5@16	—
6	#6@16	#4@16	#4@16	—	#6@16	#4@16
	#5@8	—	—	—	#4@8	—
6½	#7@8	#5@16	#4@16	—	#7@16	#5@16
	—	#4@8	—	—	#4@8	#4@8
7	—	#6@16	#4@16	—	#6@8	#5@16
	—	#4@8	—	—	—	#4@8

NOTES

1 This tank is designed for manure and live stock loads only. Do not drive tractor or spreader tank or other heavy loads on tank. Do not drive heavy loads within a distance from the tank equal to one-half the depth unless the area around the tank is paved. Use care in back filling tank walls. Pave only well compacted soil.
2 Where 2 selections of steel rienforcement are shown, either may be used

3 Forms shall be tight, straight, and well braced. Forms should be oiled to permit easy removal
4. Mortar shall be type M or type S as described in ASTM Specification C-270.
5. Sections of welded wire fabric and Dur-O-Wall will be overlapped a minimum distance of 6 inches.
6 Concrete must be evenly distributed in the forms and spaded or mechanically vibrated to assure consolidation.
7. The excavation along the outside of the walls shall be backfilled with selected material in horizontal layers not exceeding two feet in thickness. At no time during backfilling shall the surface elevation of the backfill material vary by more than two feet
8 Tanks shall be properly vented to prevent the accumulation of toxic gases

Figure 12-3.--Reinforced masonry block; walls with footings: slatted roof; length (inside) 20' to 100'; width (inside) 10' maximum; depth (inside) 4' to 7' by 0.5' increments.



SECTION ON CENTERLINE

NOTES:

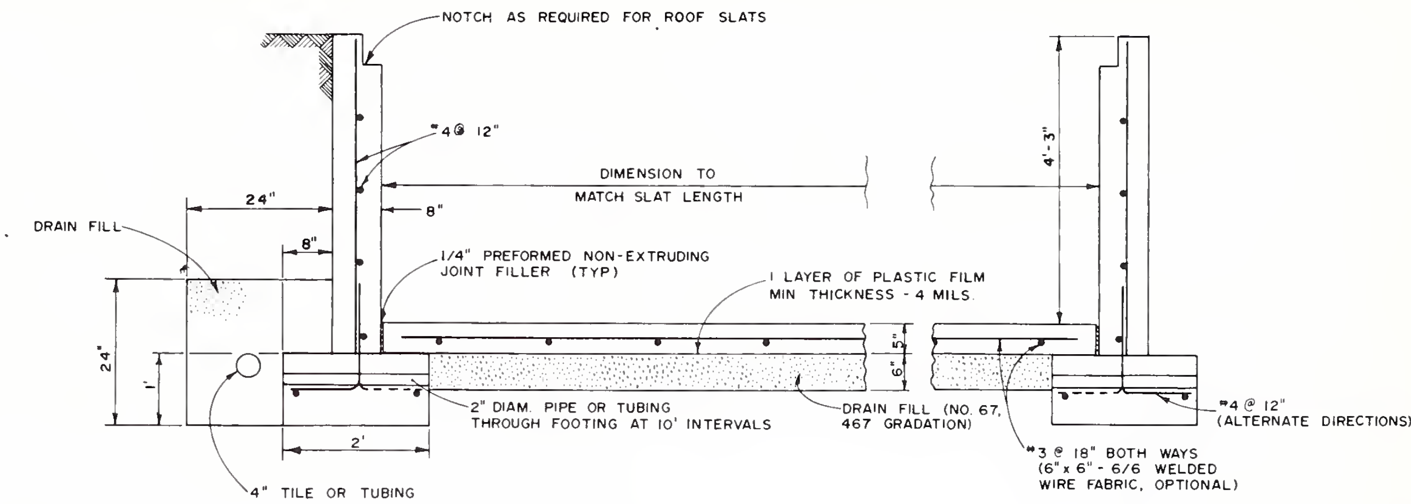
1. Cover is optionol, and moy be provided with openings os required
2. Where cover is used, 12-inch I-Beoms shall be provided with notches extending 5 inches into the woll
3. Cover is designed for 40 lb. per sq ft. live lood
4. The 3 center Beoms require diogonol hrocing os shown, with every second broce instolled the sqme direction The distonce between alternate braces is 3 feet
5. Minimum concrete ultimate strength, f'_c = 3000 psi Minimum steel working strength, fs = 20,000 psi

DRAIN FILL GRADATION (NO 67)

SIZE	% PASSING
1"	100%
3/4"	90-100%
3/8"	20-55%
NO 4	0-10%
NO 8	0-5%

NO. 467 moy olso he used

Figure 12-4.--Circular upground tank; reinforced concrete: covered roof (optional); diameter (inside) 30'; height (inside) 12'.



DRAIN FILL GRADATION (No 67)

SIZE	% PASSING
1"	100%
3/4"	90-100%
3/8"	20-55%
No. 4	0-10%
No 8	0-5%

No 467 may also be used

NOTES.

1. Minimum concrete ultimate strength fc = 3000 psi
   Minimum steel working strength fs = 20,000 psi
2. If slats are removed for cleaning, one slat should be left in place every 5 feet to support the walls
3. Wall is designed as a retaining wall to require minimum lateral support at top

Figure 12-5.--Reinforced concrete; retaining wall design: slatted roof; width - dimension according to slat length; length - variable; height 4'3".

manure and for determining the detention period are the same as those recommended for liquid tanks. The volume of bedding included can be estimated from the owner's records.

Structural Considerations

Climatic conditions and the amount of bedding in manure to a great extent determine the stackability of the manure, and stackability significantly influences the shape of the storage facility. In humid areas nonbedded manure becomes semiliquid. To prevent the saturated manure from flowing from the facility, one of the following should be considered:

1. Depressing the facility, using a concrete ramp for access.
2. Using stoplogs across access opening during wet periods.
3. Roofing the facility to keep manure stackable.

Stacking facilities should be constructed of durable materials such as reinforced concrete, reinforced concrete block, or treated tongue-and-groove lumber. The sidewalls can be of earth, but earth floors are not recommended. The floors should be of reinforced concrete.

Reinforced concrete block walls of a facility with a reinforced concrete floor are generally designed as retaining walls with the floor structurally independent of the walls. This type of design is economical for walls less than 5 ft high.

Timber sidewalls should be designed with the load on the post based on full wall height and spacing of posts (table 12-3) and the load on the planks based on wall height above each plank and space between posts (table 12-4).

Table 12-3.--Maximum wall height for wood storage facilities (based on post loading)
[No. 2 grade lumber]

Post spacing (ft)	Maximum wall height: Larch or Douglas-fir 4x6 in	6x6 in	6x8 in	8x8 in	Southern yellow pine 4x6 in	6x6 in	6x8 in	8x8 in
	ft	ft	ft	ft	ft	ft	ft	ft
2	5.1	5.8	7.1	7.8	4.8	5.5	6.7	7.4
4	4.0	4.7	5.6	6.2	3.8	4.4	5.3	5.8
6	3.6	4.0	4.9	5.4	3.4	3.8	4.6	5.1
8	3.2	3.7	4.5	4.9	3.0	3.5	4.2	4.7
10	2.8	3.4	4.0	4.6	2.8	3.2	3.9	4.3
12	2.6	3.2	3.7	4.2	2.5	3.0	3.6	4.0

Table 12-4.--Maximum wall height for wood storage facilities (based on plank loading)
[No. 2 grade lumber, planks 1.5 in thick]

Post spacing (ft)	Maximum wall height: Larch or Douglas-fir	Maximum wall height: Southern yellow pine
	ft	ft
2.........	20.9	17.6
3.........	9.6	8.1
4.........	5.6	4.6
5.........	3.8	3.2
6.........	2.8	2.4

The reinforced concrete floor should have expansion joints at approximately 30-ft intervals. If freezing and thawing is a problem, the concrete slab should be poured over a bed of gravel or other free-draining material.

Structural details for a typical manure stacking facility with timber sidewalls and reinforced concrete floor are illustrated in figure 12-6.

Effluent Disposal

Any leakage from the manure stacking facility must be removed to prevent pollution of surface or ground water. Collection ponds or sod filter areas are commonly used for effluent disposal.

EARTH STORAGE FACILITIES

Location

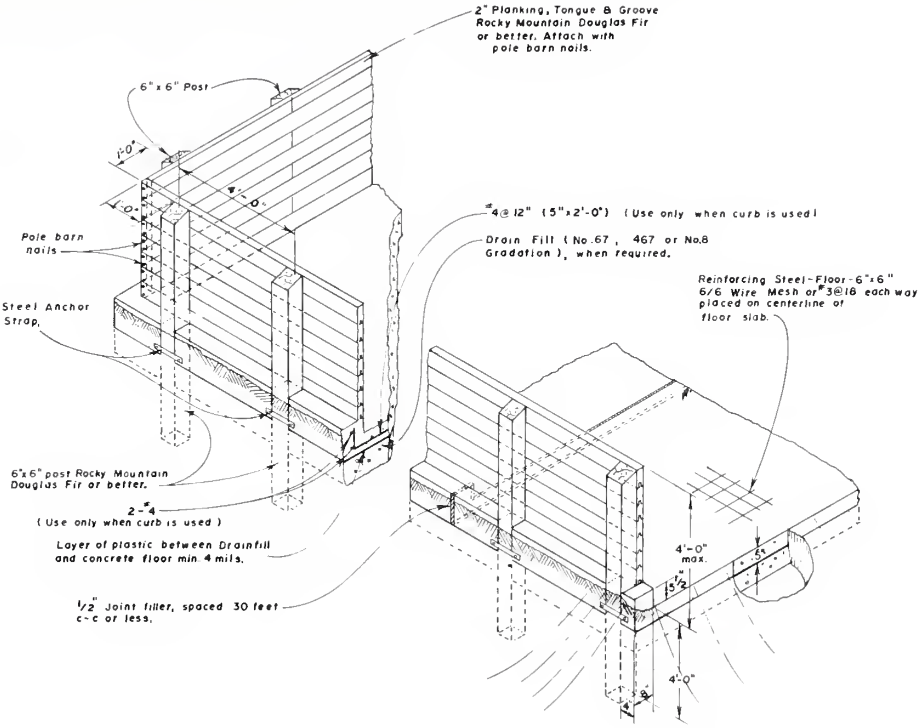
Earth storage facilities must be located in areas unaffected by seasonal water tables or surface runoff. Aboveground reservoirs are often used in humid areas where the seasonal water table approaches the ground surface.

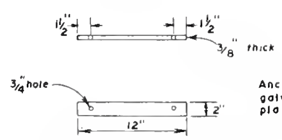
Size

The number, type, and average weight of animals; design detention period; average rainfall for detention period; and amount of wash water and bedding determine the size of the facility. The volume of manure and the season and length of the detention period should be determined as they are for liquid tanks.

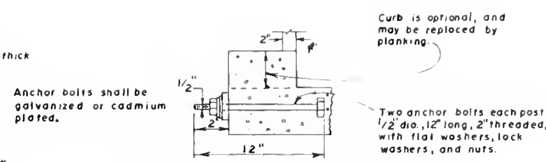
Structural Considerations

Both the sidewalls and bottom of the facility should be of impermeable materials. If earth embankments are used for sidewalls, the construction requirements are the same as for earth dams.





ANCHOR STRAPS *



DETAILS OF ANCHOR BOLT AND INSTALLATION

* Where earth backfill is placed 30" high on the outside of the walls, the straps may be eliminated.

NOTES:
1. Posts and planking shall be pressure treated.
2. Expansion joints in the floor slab shall be spaced no farther apart than 30 feet c-c. Use 1/2" min joint filler in these expansion joints.
3. Joint filler shall be preformed; bituminous, sponge rubber, cork, or expanded cork, as described in ASTM Designation D-994, D-1751, or D-1752.

BILL OF MATERIALS

DESCRIPTION	SIZE
Wooden Post	6 x 6 x
Plank, tongue & Groove	2 x x
Anchor Strap	3/8" x 2" x 12"
Anchor Bolt, w/ nut & washers	1/2" x 12"
Joint filler, 1/2"	
Concrete	
Reinforcing steel-#4 Bars	
Reinforcing steel - 3 Bars	
or 6'x6' 6/6 wire mesh	
Granular backfill, No 8, 67 or 467	
Pole Barn nails	

Figure 12-6.--Standard manure storage area.

PART III - DEBRIS BASINS (SETTLING FACILITIES)

1. GENERAL

Debris basins or settling facilities, when required, are a major component of any waste management system. They are used to remove or settle out most of the solid waste material. The liquid waste and some fine particles of solid waste and soluble solids then move to holding ponds, lagoons, or evaporation ponds. The debris basins are allowed to dry periodically, and the solid wastes are removed, usually with a front-end loader, and hauled to a land disposal area for spreading. Two-cell basins used alternately permit longer periods for drying and for removal of solids.

2. TYPES

There are three general types of settling basins: ponds, channels or diversions, and tanks. Settling ponds are constructed by placing an earthfill across a natural draw or depression to create a reservoir area or by excavating a pond on relatively level ground and placing the excavated material around the pond as a dike to increase the depth. Settling channels or diversions are constructed as waterways or diversions. In addition to moving the liquid waste and runoff from precipitation, channels or diversions serve as settling facilities. Settling tanks are set partially or entirely below ground level; one side is sloped as an apron or ramp to facilitate removing solid waste with a front-end loader.

3. OUTLETS

There are three general types of outlets from settling facilities: flow-through (no control), perforated or slotted risers, and various types of screened or baffled outlets.

In flow-through basins the mixed solid and liquid wastes enter one end of the basin and flow freely out the other end; the heavier solids settle to the bottom during travel through the basin. When the solids build to the lip or crest of the outlet, it is time to remove them and start a new cycle. A flow-through basin is the least effective in removing solids. But its effectiveness can be improved if the basin is large, the path of travel is long, and the velocity is low. Flow-through basins are more efficient in removing solids from swine, poultry, and other wastes that settle out than from cattle wastes in which many solids float on the surface.

Perforated or slotted risers are effective for all types of waste since they can draw liquid wastes from any level of the basin. But they may become plugged with straw or fibrous material and require considerable maintenance. They are used extensively in settling channels with blocked ends but do not generally function so well in basins and tanks. In at least one state in the Midwest it has been found that vertical slots 1 inch by 4 inch work well in settling facility risers located below beef feedlots.

Various types of screened outlets or outlets with trash racks have been used with success, depending on the velocity of flow at the outlet structure. Such outlet structures should be designed with multiple sets of screens or racks so that each screen or rack can be removed and cleaned while others remain in use. Skimmers and baffles around screened outlets are helpful in holding back floating materials.

4. SETTLING FACILITIES FOR FEEDLOTS

TYPES

Waste management facilities for feedlots usually include a diversion above the lot to direct clean runoff away from the feedlot and a collection channel below the feedlot to collect the mixture of urine, feces, and surface runoff. Most of the runoff from a feedlot occurs during and after periods of heavy precipitation, and only part of the solid waste, less than 25 percent, ever reaches the collection ditch. Normally, only 3 to 6 percent of the manure deposited on feedlots is removed by runoff. A major part of the solid manure remains and is removed periodically by mechanical means.

DESIGN

A collection ditch or channel below the feedlot can be an effective settling basin if it is properly located and designed. It should be located on the outside of the pen for easier cleaning and maintenance; it should have a cross section with a flat bottom at least 10 ft long and side slopes of 8 to 1 or flatter. The gradient should allow a velocity of flow under design storm conditions of not more than 1 ft/sec. The design capacity should be consistent with the most stringent level of protection required for the overall system. Designs based on runoff from either a 10- or 25-year, 24-hour rainfall event are currently required by EPA. Such data are available for most locations. Refer to SCS Engineering Practice Standard 362 for additional design criteria for diversions and also to chapters 7, 8, 9, and 14 of the SCS Engineering Field Manual.

OUTLETS

Both primary and secondary outlets or spillways are commonly used on collection structures below feedlots. The primary spillway is usually a perforated or slotted riser or risers at the low point or points in the collection structure. These primary spillways collect the liquid waste and normal runoff from the feedlot and carry it to a holding pond.

A secondary or emergency spillway diverts excessive storm-water runoff from the collection structure to the holding facility. For this reason, reserve capacity should be provided in the holding facilities as discussed in part VI of this chapter.

Adverse topographic conditions or lack of space may prevent locating a diversion collection channel below the feedlot. If so, the waste

and runoff are conveyed directly to the next facility, which is usually a holding pond. This waste will contain considerably more solids than is usually directed to a holding pond and may require agitation and special handling for pumping or removal.

5. SETTLING FACILITIES FOR WASTES FROM CONFINED DAIRY, SWINE, AND POULTRY

TYPES

The waste in confined housing consists mostly of urine, feces, and water used for washing, flushing, or watering. Waste water from flushdown systems may contain some bedding materials. If the animals are housed, precipitation is not a factor since it is collected and diverted to other disposal areas apart from the waste material. The waste from a single confined-housing operation usually remains constant since the amount of wash water used is controlled and does not vary greatly from day to day or month by month. If a settling facility is used, all the waste goes directly to this facility and contains considerably more solids than the runoff from a feedlot or open-pen confinement.

The settling facilities used on dairy, swine, and poultry farms are usually settling ponds or tanks located near the barn, milking parlor, sheds, or other enclosures. The urine, feces, and any bedding are sluiced directly into the settling facility.

It is usually desirable to have the entry for the waste at one end of the settling facility and the outlet at the opposite end so as to obtain a maximum distance for settling. It is also desirable to have the waste enter the settling facility with the least turbulence possible. Removable baffles similar to those used in septic tanks are helpful.

SETTLING CHARACTERISTICS OF MANURE

The settling characteristics of the manure affect the design of settling ponds or tanks. Solids in poultry manure usually settle to the bottom rapidly. Swine manure tends to stay in suspension unless antibiotics that cause solids to settle to the bottom are used. Cattle or dairy manures tend to float on the surface. All manure contains some food residue, grit, and sand that settle to the bottom rapidly. Part of cattle manure goes to the bottom of a settling basin, some of the fine particles stay in suspension, and a part floats on the surface. This creates stratification in which most of the relatively clear liquid effluent is at mid-depth in the basin. Outlets should be planned for drawing off the liquid effluent below the floating layer. Inverted risers and baffles at the outlet are effective, but they may give trouble under prolonged freezing conditions.

The rate at which solids settle from liquid manure depends on the amount of dilution water. Settling improves as the moisture content increases. Manure as excreted forms a thick slurry ranging from about 75 percent moisture for poultry to 90 or 91 percent for swine. Almost

no solids settle from such slurry. Sheep and horse manures are even dryer and can be handled as solid wastes.

Little settling of solids occurs in holding tanks or pits of manure to which little water is added. Some sand, grit, and food particles settle and form a more solid mass at the bottom of the tank. The slurry near the bottom usually has slightly less moisture than that above. Cattle manure may form a solid layer of lighter material on top of the liquid slurry. Agitation of the tank or pit contents is required to obtain uniformity for removal as a liquid slurry.

Water added in flushing systems dilutes manure and yields a mixture in which some settling occurs. The moisture content of such a mixture usually ranges from 96 to 99 percent or more. Research indicates that as much as 50 to 60 percent of the total solids in a liquid manure of 97.5 percent moisture content is retained in a quiescent settling facility. This settled material does not form a solid layer on the bottom but is contained in a thicker slurry in the lower part of the tank with a more diluted mixture above.

In practice, the turbulence of liquid wastes entering a settling facility together with a slight velocity of flow through the facility tends to reduce settling efficiency. Accumulation of solids in the facility also reduces efficiency by allowing a discharge of liquid with a higher solids content than was discharged when the operation was initiated.

With good design and frequent cleaning, a settling facility receiving liquid manure of 97 to 98 percent moisture content discharges a liquid of about 1 to 1-1/2 percent solids. This reduction is of particular importance in designing treatment facilities receiving such discharge. For example, liquid dairy manure with 2.6 percent solids content directed through a settling tank was discharged as a liquid with 0.9 percent solids content. Over several months a floating layer of 13 percent solids content formed. A bottom layer of slurry with about 4.5 percent solids content formed and the intermediate layer averaged 1.5 percent solids.

OUTLETS

All outlet structures for settling facilities are troublesome and can be plugged or frozen. Therefore, they should be designed so that they can be easily cleaned, rodded, or flushed. Open-type weirs, flumes, or chutes are preferable to closed-pipe outlets with bends or elbows. If pipe conduits are used, they should have a straight alinement.

An outlet structure that seems well suited to settling facilities is a flashboard overflow weir. The gate opening extends from the floor of the basin to the top and has grooves for inserting flashboards that can be added or removed as desired. Flashboards can be added during filling to get the desired depth of basin; the liquid effluent spills over the top flashboard, which acts as a constricted rectangular weir. The length of the weir governs the velocity of approach to the weir. It is desirable to keep the velocity as low as possible by providing a long weir. However, the hand labor needed for inserting or removing

the flashboards limits the length to about 3 feet. Flashboards are usually 2- by 6-inch or 2- by 8-inch planks that have been pressure treated. Multiple gates can be installed in large structures for greater outflow capacity. After the basin or pond has filled with solid material, the flashboards can be pulled one by one to allow further dewatering of the solids, which hastens the drying period. If this type of outlet structure is used for settling facilities for cattle wastes, a removable baffle just ahead of the weir structure prevents floating wastes from going over the weir. This removable baffle is similar to baffles used in septic tanks and should extend about 1 ft below the weir crest.

6. DESIGN OF SETTLING BASINS, TANKS, AND PONDS

VOLUME

The design of settling facilities involves more than hydraulics. Volume is based on (1) the amount of settleable solids to be accumulated for the storage period, (2) practical depth of the facility if maintained in continuous operation, and (3) whether rainfall or runoff is to be admitted to the facility. Expressed mathematically:

$$V_{min} = V_{ss} + V_r$$

where

V_{min} = Minimum volume (less freeboard volume)
V_{ss} = Volume of settleable solids accumulated between cleanouts
V_r = Volume of runoff and direct precipitation to be retarded to allow time for settling of solids.

As previously discussed the volume of storage required for the settled solids is difficult to estimate. From current information it appears that settled solids concentrate in sludge with a solids content of about 6 percent at the bottom of the tank. It also appears that about 30 percent of the solids can be settled from an inflow of liquid manure containing 2 to 3 percent solids from flushing systems.

On this basis the volume of storage needed for settled solids is equivalent to the volume of sludge with 6 percent solids content containing 30 percent of the total solids directed to the settling facility. This volume should be provided below the elevation of the outlet.

For example, the volume required for the settled solids in a settling facility serving 50, 1,200-lb dairy cows:

$$\text{Solids excreted} = 510 \text{ lb/day}$$

$$30 \text{ percent of } 510 = 153 \text{ lb/day}$$

$$\text{6-percent sludge} = \frac{153}{0.06} = 2{,}550 \text{ lb/day}$$

$$\text{Volume required} = \frac{2{,}550}{62.4} = 41 \text{ ft}^3\text{/day}$$

One reference suggests that a settled solids capacity of 200 ft^3 per cow will serve a flushing system with liquid manure with 2.8-percent solids content for 6 months.

Settling facilities have been used more for separating solids from feedlot runoff than for separating solids from the effluent from manure flushing systems. Volume recommendations for feedlot-runoff settling facilities still vary. The most common criterion is 10 percent of the holding pond capacity or 1 inch of runoff, whichever is greater. Another suggestion is to provide 850 ft^3 solids storage for each acre of drainage area.

If the solids content of feedlot runoff can be estimated, it can reasonably be assumed that 40 to 60 percent of the total solids will be retained in settling facilities. The volume these solids will occupy depends on their moisture content. If the solids are submerged in liquid, the moisture content will probably be 90 to 95 percent. If the settling basin is drained and the solids are dried, the moisture content will depend on climate and will range from 50 to 60 percent in arid areas and from 80 to 90 percent in humid areas.

Records of local experience are the best guide in determining the volume necessary for settled solids in feedlot-runoff settling facilities.

CONTINUOUS-OPERATION SETTLING BASINS

There is a practical limit to the depth of continuous settling facilities (facilities from which the settled solids are removed periodically and the facility put back into operation). It is difficult to dry and remove a layer of solid wastes more than 3 ft deep from the bottom of a settling basin. Therefore, the volume (cubic feet) of settled solids to be accumulated for the storage period should be no more than three times the surface area (square feet) for basins or tanks with vertical walls. These figures show the necessary floor or surface area but do not establish the tank depth. The total tank depth is equal to the sum of the depth required for settled solids (3 ft maximum in this example) plus the additional depth required for the temporary storage of runoff and precipitation, if any, and allowance for freeboard. One foot additional depth and at least 6 inches for freeboard are customary if there is no other specific information. On the basis of these data, a 4-1/2-ft depth is specified for the tank. The product of the length and the width multiplied by 3 should equal the volume of settled waste accumulated annually. This presumes that the tank or basin is cleaned annually. If the tank is cleaned more frequently, the allowance for volume can be adjusted accordingly.

The rate at which waste is admitted to the settling facility varies according to the type of washdown or flushdown cleaning used. In large flushdown operations several hundred gallons of wash water may be released almost instantly and may reach the settling facility within a few minutes. Additional tank or basin storage is needed for this peak loading. Each settling facility must be sized according to the special type of flushdown operation used. Flow-through settling facilities are not too well suited to large flushdown operations because the turbulence caused by peak loading disturbs the natural settling process.

TWIN-CELL SETTLING BASINS

Twin-cell or compartment-type settling basins have considerable merit. The settling tank or basin is divided into two or more compartments, each with a separate inlet and outlet. Waste is directed to one cell until it is full and ready for cleaning; then the waste is directed to the other cell while the first one is draining and drying and the solids are being removed. This arrangement allows a long drying period, which is important since the saturated solids in a tank drain and dry slowly.

The previous discussion has been directed toward the design of fabricated settling basins planned for continuous use. Such basins usually are reinforced-concrete tanks or basins, and the structural design criteria are the same as those for concrete holding tanks. The only difference is that a settling basin or tank often has a sloping wall or apron designed as a ramp to admit front-end loading equipment for removing the settled solids. This ramp and the floor of the tank or basin must be designed to support a wheel-type tractor with front-end loader and a full load of damp manure.

SETTLING PONDS

Settling ponds of earth construction are also used as continuous settling facilities. Their general function and operation is the same as for tanks and basins previously discussed. For these ponds it is desirable to have a concrete slab floor for ease of cleaning with a front-end loader, but this is not a necessity. It is also desirable to have a concrete ramp into the pond to facilitate travel of a front-end loader to and from the pond since the banks and side slopes of the pond are wet and saturated with liquid waste.

Full-depth stoplog outlets work well in ponds and can be framed with concrete or treated lumber. During drying and cleaning, the stoplogs can be loosened to permit seepage of liquids from the settling pond to facilitate drying. The outlet structure should be located at the lowest point in the pond so that the pond is completely drained when the bottom or lowest stoplog is removed.

It is desirable to have two small settling ponds rather than one large one so that they can be used alternately to facilitate drying and cleaning. The principle is the same as for a two-cell settling tank.

BATCH-TYPE SETTLING FACILITIES

Batch-type settling facilities are settling ponds or channels that are used once and abandoned. They are used where land is plentiful and cheap. When the first pond fills, a new one is excavated adjacent to the old one, and the excavated material or spoil is used to fill the abandoned pond. This procedure is similar to strip mining. In arid areas where the net annual evaporation is great, evaporation ponds are used for both a settling and an evaporation basin for liquid waste. When evaporation ponds become filled with solid waste to the point that they do not function as planned, they must be cleaned out or abandoned and a new pond constructed.

Both types of settling facilities, continuous and batch, become anaerobic, and odor may be a problem in urban or other populated areas.

PART IV - DISPOSAL LAGOONS

1. GENERAL

Lagoons are impoundments for liquid wastes made by constructing excavated pits, dams, embankments, dikes, levees, or a combination of these. Lagoons are constructed for decomposition of organic waste by aerobic or anaerobic organisms. National and state SCS engineering standards for disposal lagoons (Code 359) provide design criteria.

2. AEROBIC

Aerobic lagoons have proved effective for intermediate treatment of wastes in agricultural waste management systems. They are desirable because they do not produce odorous gases. If aerobic lagoons are properly designed, constructed, and managed, good reduction of BOD and destruction of coliform organisms result. There is some accumulation of fixed solids and slowly degradable volatile solids. Although the effluent is not generally suitable for discharge to surface waters, it is high in dissolved oxygen and suitable for various methods of land application.

NATURALLY AERATED LAGOONS

A naturally aerated lagoon is a shallow basin, 2 to 5 ft deep, for treating wastes by storage under climatic conditions (warmth, light, wind) that favor the introduction of atmospheric oxygen and the growth of algae. Bacterial decomposition of the wastes releases carbon dioxide that promotes the growth of algae. Ammonia is converted to nitrates, which along with mineralized phosphorus are used by the algae. The driving force in this type of self purification is photosynthesis, supported by the close association between the bacteria that digest organic matter and the algae. The lagoon is relatively odor free but a large surface area per animal unit is required.

Planning the Lagoon

Practical planning must be a cooperative effort between the planner and the owner and must be done on the premises to select the best sites. Consideration should be given to long-range needs for the lagoon, suitability of the surrounding land for effluent disposal, soils with good water-holding capacity, possible use of gravity flow, good exposure to sun and wind, and proximity to the waste source, farm buildings, roads, and neighbors. Another consideration is accessibility for construction equipment. Often a small lagoon costs approximately as much as a larger, more workable lagoon.

Location

The site should be near the source of waste but as far from inhabited dwellings as practical. The minimum distance should be about 300 ft. The site should be located so that the prevailing winds in summer carry odor away from the house and public areas.

The lagoon should be located and constructed so that runoff from outside drainage areas cannot enter the lagoon.

Soils and Foundation

Lagoons should be located on soils of low permeability or soils that are suitable for sealing. Contamination of the ground water should be prevented by avoiding soils with a high water table, sandy or gravelly soils, or shallow soils over fractured or cavernous rock.

Water Supply

Enough water should be available to fill the lagoon before loading and to maintain it during operation.

Temperature

The temperature of the lagoon contents affects the rate of biological activity. Biological activity decreases as temperature decreases. Ice and snow cover on aerobic lagoons reduces sunlight penetration and the growth of algae necessary for providing oxygen. Under these conditions biological activity is reduced. Loading rates should be lower and detention time longer in cold climates than in warm climates.

Loadings

Aerobic lagoons are designed on the basis of the daily BOD_5 loading per acre of surface area. Tables 4-1, 12-5, and 12-6 show the general range of BOD_5 production by livestock species. Local data should be used when available. Allowable loadings for aerobic disposal lagoons must be in accordance with state requirements.

Table 12-5.--Production of livestock and poultry wastes

Animal	Manure	BOD_5	Volatile solids
	lb/day/1,000 lb animal		
Dairy cattle........	84	1.7	7
Beef cattle.........	84	1.7	8
Horses..............	56	1.4	8
Sheep...............	40	2.5	8.6
Hogs................	57	2.2	4
Poultry.............	63	3.8	11

Table 12-6.--Average production of constituents in waste water from ducks on water[1/]

Wastes produced (gal/day/ 1,000 ducks)	BOD_5	Chlorine demand	Suspended solids Total	Suspended solids Volatile	Total nitrogen	Total phosphorus	Soluble potassium
			lb/day/1,000 ducks				
18,500 (average)..	20.6	1.6	96	58	5.7	7.6	3.6
34,200 (maximum)..	30.4	2.1	123	70	6.4	10.5	4.6
10,800 (minimum)..	16.5	1.2	52	35	4.7	4.7	2.5

[1/]Quantity per 1,000 ducks used because of usual weight distribution of slaughter ducks having access to swim water.

Operational Notes

Startup

It is best to start a new lagoon operating during warm summer weather. The bacteria will be more active and will multiply and develop a strong base before cold weather. Daily loading is important to provide the food supply and maintain the energy of the biological organisms. Lagoons that are fed daily can withstand occasional shock loadings and remain aerobic.

Level Control

In northern climates the operating level can be lowered for winter storage before ice forms. In the spring the level can be lowered again, allowing shallow operation at gradually increasing depths to discourage emergent vegetation during the summer.

Maintenance

Bedding material, grass clippings, oil, and floating debris should be kept out of the lagoon. Floating algae aid the aerobic process and should not be removed. The lagoon should be inspected periodically, any rodent damage repaired, the vegetation clipped, and the embankment and edges kept free of tall weeds, shrubs, and trees.

Field Observations

Observations of aerobic lagoons used for 2 years in the Northeast for treating milking center wastes indicated the following:

1. Contrary to reports of other studies, winter icecaps did not prevent aerobic digestion. Dissolved oxygen was present all winter, and BOD levels continued to decline.
2. When the influent lines were not submerged, milking center wastes froze across the surface in layers as ice appeared in the lagoons.

3. Surface accumulations of snow varied according to topography and prevailing winds. The range was from no snow accumulation to complete filling with snow.
4. Temperatures at the bottom of the lagoons were higher than temperatures directly below the icecaps.
5. Settling tanks in the waste line between the milking centers and the lagoons were found practical. The capacity of these tanks was based on 18 gal per cow. The tanks should be cleaned two to three times a year. The cover should be sectioned for easy removal for cleaning.

3. ANAEROBIC

Anaerobic lagoons are widely used because of low initial cost, ease of operation, smaller area required, and lack of alternatives. They have proved to be useful components of overall systems for waste management. They provide storage for manure in northern areas when winter spreading of animal waste is not feasible. In central United States anaerobic lagoons are used for both decomposition of wastes and storage of manure. The goal is to provide both without offensive odor or water pollution.

The trend to larger animal-confinement units is putting new demands on handling, treatment, and disposal facilities for manure. More hydraulic waste-transport systems that require more dilute and partially treated wastes are being used. For these installations, anaerobic lagoons can be designed and managed to provide significant organic removal, solids storage, and volume reduction at low levels of odor production.

THE ANAEROBIC PROCESS

The anaerobic decomposition of wastes depends on anaerobic and facultative bacteria. The environment is not suitable for the growth of algae, aerobic bacteria, or higher animals.

The anaerobic digestive process is complex. Proper environmental control is basic to the anaerobic digestive process, which has two principal phases, acid forming and acid recovery.

Acid-Forming Phase

Micro-organisms hydrolyze organic matter and metabolize the products to organic acids, alcohols, sulfides, amines, and carbon dioxide. No single group of bacteria is able to degrade the variety of raw materials present in animal wastes. Therefore, the bacterial population is heterogeneous. Its composition is a function of both the nature of the wastes and the temperature and pH of the lagoon. In this phase insoluble substances are liquefied by the action of specific enzymes that allow further metabolism of these materials.

Cellulose, hemicelluloses, pectins, lipids, and proteins are the more common classes of materials partly decomposed by enzyme activity. Lignins are largely unchanged in anaerobic decomposition. The hydrogen acceptors in the initial breakdown of complex organics are nitrate and

sulfate ions as well as the oxygen combined in organic compounds. Typical reactions during this phase include:

$$\text{organic matter} + \text{sulfate-reducing bacteria} + SO_4 \longrightarrow \text{more bacteria} + \text{organic intermediates} + H_2S + CO_2 + H_2O + \text{energy}$$

$$\text{organic matter} + \text{facultative bacteria} \longrightarrow \text{more bacteria} + \text{organic intermediates} + CO_2 + \text{energy}$$

Intermediate breakdown products during this phase of digestion include hexoses, such as glucose, mannose, fructose, etc., from the cellulose and hemicelluloses. The various hexoses may be further degraded to short-chain acids, alcohols, ketones, and aldehydes. The pectins yield methanol and glacturonic acid. The major products from lipid degradation are fatty acids and glycerol. Proteins are successively hydrolyzed into peptides and amino acids.

The net result of organic degradation during this phase of digestion is the conversion of many of the insoluble raw materials into soluble intermediate products. This produces a concentration of organic acids great enough to depress the pH and virtually stop anaerobic digestion. For this reason this phase must occur in the presence of organisms that can utilize the intermediate products.

Acid-Recovery Phase

To maintain anaerobic digestion, the intermediate products of the breakdown must be converted to successively simpler compounds and suitable end products. Hexoses yield acids of shorter chains and alcohols with fewer carbon atoms than do the fatty acids and glycerols. Amino acids are broken down into the ammonium ion and appropriate acids. Hydrogen sulfide and various mercaptans are produced from the sulfur-containing amino acids.

The methane bacteria convert short-chain acids and alcohols to methane and carbon dioxide, thus preventing a buildup of acids within the system. A proper balance is required between the organic feed rates and the methane bacterial population.

Methane bacteria are strictly anaerobes and require the presence of an ammonium ion as a nitrogen source. Several species have been isolated, each having specific substrate requirements. As an example, Methanobacterium suboxydans utilizes butyrate and valerate but not acetate. Several other species are able to utilize acetate, but no single species is able to utilize the full range of substrates.

Tracer studies have shown that methane formation proceeds in two separate ways. Methane can be formed by the reduction of carbon dioxide by hydrogen:

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

The second kind of reaction in methane production is represented by the decarboxylation of acetic acid:

$$CH_3CO_2H \longrightarrow CH_4 + CO_2$$

Considerably more work is needed to reach a full understanding of methane bacteria. Only recently have the various species been isolated in pure culture. Little is known concerning the enzymes that moderate the various reactions.

PLANNING CONSIDERATIONS

Anaerobic lagoons should be 8 to 15 ft deep. Deep lagoons have these advantages:

1. Smaller surface area allows better temperature and environment for methane bacteria and minimizes escape of odors.
2. Rising gas bubbles encourage better mixing.
3. Less land is required.
4. Mechanical aeration is efficient in controlling odor if necessary. A rough guide is 1 lb O_2/1b BOD_5.

INLETS

Near-center loading appears to be best in anaerobic lagoons. Sizable deposits accumulate with edge loading.

Freezing of above-surface influent lines can be prevented by putting a tight stopper or valve at the building to prevent dribble flow or by insulating the exposed influent pipe and turndown elbow on the end.

Submerged influent lines require enough head to overcome submergence. If wastes contain large amounts of solids, access for rodding should be provided to prevent plugging at the waterline.

The items to be considered in selecting a location are generally the same as for aerobic lagoons except for the extra distance needed because of the possibility of odor.

DESIGN AND CONSTRUCTION

Loadings

Anaerobic lagoons are designed on the basis of the daily BOD_5 or volatile solids per 1,000 ft^3 of lagoon volume. The loadings allowed must be in accordance with state requirements. Figure 12-7 shows loadings generally recommended in different zones of the country.

OPERATION AND MANAGEMENT

The following practices will help to keep an anaerobic lagoon functioning properly:

1. Fill to required water volume before loading.
2. Add water as needed to maintain design level.

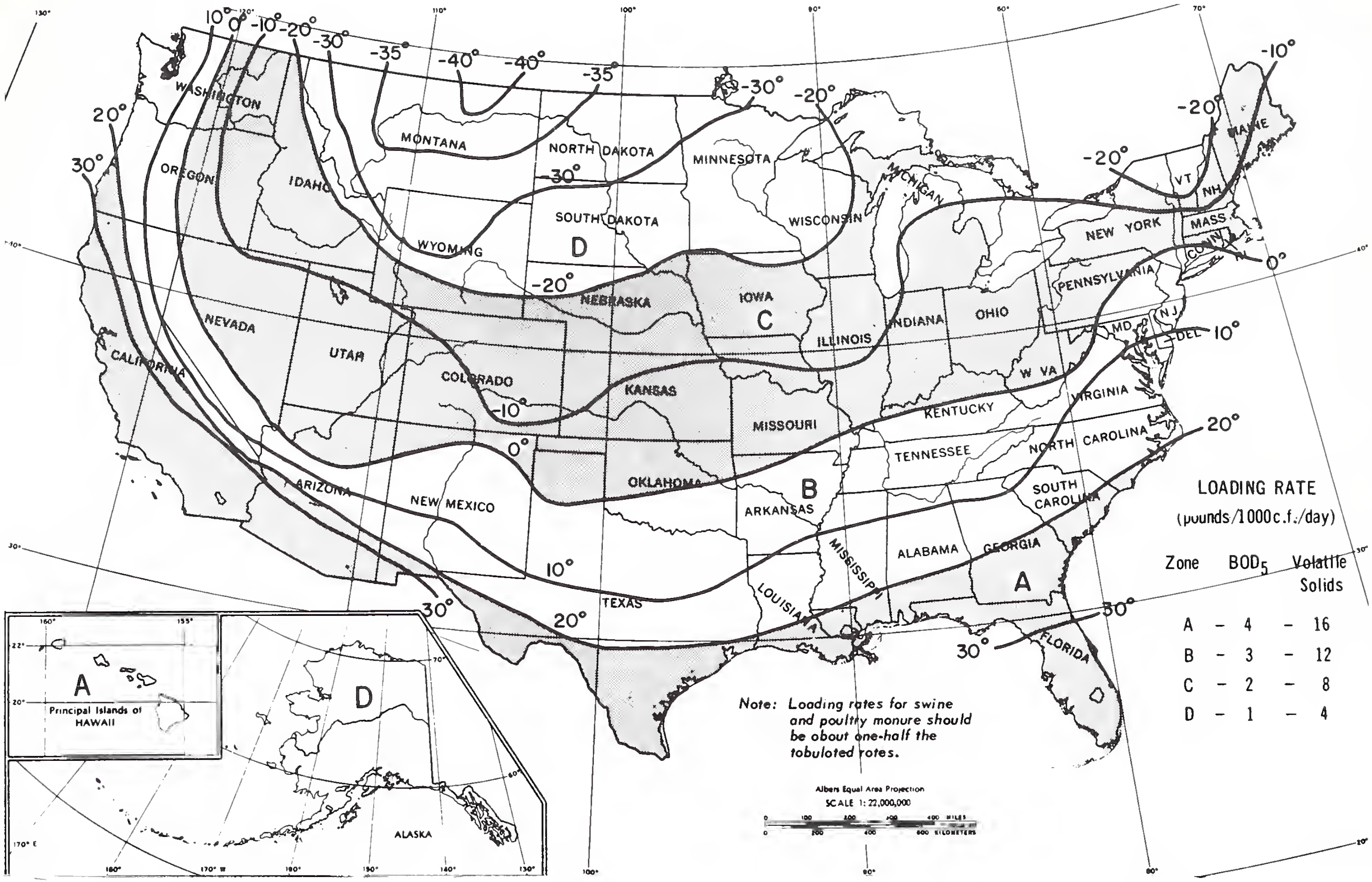


Figure 12-7.--Anaerobic lagoon loading rates by zones (from ASHRAE 1963 Guide).

3. Start at beginning of warm weather. There is almost no activity when the liquid temperature is below 45^{o} F. Best operation is at temperatures of 70^{o} to 130^{o} F.
4. Measure pH frequently. Most problems with anaerobic lagoons are related to pH in some manner. The optimum pH is about 6.5. When pH falls below this level, methane bacteria are inhibited by the free hydrogen ion concentration. The most frequent cause of low pH in anaerobic digestion is shock loading of organic material that stimulates the facultative acid-producing bacteria.
5. Add hydrated lime or lye if pH is below 6.5. Add 1 lb per 1,000 ft^2 daily until pH reaches 7.
6. Load daily.
7. Do not exceed design loading rates.
8. At least annually plan to remove part of the contents to prevent overflow and apply it to the land. If evaporation exceeds rainfall in a succession of dry years, remove part of the contents and refill with water to maintain nitrogen, phosphorus, and potassium levels and to prevent concentration of toxic material. Materials that are toxic to anaerobic bacteria are copper, hexavalent chromium, nickel, zinc, calcium, magnesium, sodium, potassium, and ammonia.
9. Maintain the same vegetative conditions as for aerobic lagoons.

OTHER DESIGN CONSIDERATIONS - AEROBIC AND ANAEROBIC

Earth Embankment

Top width.--The minimum top width is 8 ft.

Side slopes.--The combined side slopes of the settled embankment should be no less than 5 horizontal to 1 vertical.

Freeboard.--The minimum elevation for the top of the settled embankment is 1 ft above the surface of the water in the lagoon.

Allowance for settlement.--The design height of the embankment should be increased by the amount needed to insure that the design top elevation is maintained after settlement. This increase should be no less than 5 percent.

Depth

The minimum depth of liquid storage space is 6 ft for anaerobic lagoons and 2 ft for aerobic lagoons. The maximum depth for anaerobic lagoons is dictated by the site and needs. The maximum depth for aerobic lagoons is 5.0 ft.

Bottom

The bottom of aerobic lagoons should be approximately level to prevent formation of septic pockets.

Edges

The edges of the lagoon below the planned waterline should be deepened to a stable slope as steep as soil conditions permit to reduce areas of shallow water and inhibit weed growth.

Inlet

If freezing is not a problem, an open inlet such as a concrete ditch can be used. If freezing is a problem, the inlet should be a pipe with a minimum diameter of 6 inches and a minimum slope of 1 percent. The inlet pipe should terminate near the center of the lagoon. It should be far enough below the surface to protect it from freezing, or other protective measures should be provided. Access to the pipe should be provided for rodding if it becomes blocked.

Outlet

An overflow pipe should be installed so that water is discharged from a point at least 6 inches below the surface when the maximum water level is reached. A vented elbow or turndown on the outlet pipe entrance can be used for this purpose.

Protection

As a safety precaution the lagoon should be fenced and warning signs posted.

Erosion Control

The embankment and surrounding areas should be vegetated for protection against erosion.

4. SURFACE AERATED LAGOONS

GENERAL

Naturally aerobic lagoons used for treating animal and poultry manure must have a large area to have enough oxygen. A lack of suitable sites and the high cost of large lagoons have forced consideration of other methods of storage and treatment.

Surface aerators for oxygen transfer in lagoons have been used successfully for treating municipal wastes, wastes from food processing and papermills, and animal and poultry manure. Aerated manure lagoons require a surface area about 5 percent of that of aerobic lagoons and contain about the same volume as anaerobic lagoons used for treating the same wastes.

As is true for aerobic lagoons, the effluent from aerated lagoons treating manure is not generally suitable for discharge to surface waters.

DESIGN

Experience to date indicates that the addition of 1 lb O_2 for each pound BOD_5 contributed per day provides satisfactory odor control.

The following design information is based on the surface aeration required for complete degradation of wastes.

Lagoon Volume

Research has not provided specific recommendations relative to minimum volume requirements for aerated lagoons treating livestock wastes. But it appears that detention time and management of the lagoon effluent dictate lagoon volume.

As a guide, the volume should be great enough to store a 1-year output of manure plus wash water or dilution water. Enough dilution water should be provided to maintain the total solids content of the lagoon liquid below 5 percent (50,000 ppm).

A 1-year storage volume (detention time) allows for initial loading, after the lagoon has been half filled with water, and for subsequent drawdown twice a year as crop and labor requirements may dictate. If drawdown only once a year is planned, a 1-1/2-year storage volume should be provided. The rainfall expected in excess of evaporation for the period between drawdowns should be considered in determining lagoon volume.

Sludge Buildup

In an aerobic lagoon with just enough agitation to disperse oxygen throughout the liquid contents, a sludge volume of 1 ft^3 for each 13 lb of contributed volatile solids can be expected. But since the horsepower (hp) required for oxygen transfer in aerated manure lagoons is usually somewhat greater than that necessary for oxygen dispersion, a large proportion of the solids are suspended throughout the liquid. Lagoon drawdown carries suspended solids with the effluent, and sludge buildup is reduced substantially. There is also evidence that aneraobic decomposition within the bottom sludge accumulation further reduces the volume over a long period of time.

The volume of sludge accumulation to expect can be estimated on the basis of 1 ft^3 of sludge for each 20 to 30 lb of volatile solids. For design, selection of the rate of accumulation within this range should be related to the degree of mixing and suspension of solids expected. Experience may indicate that other values should be used.

Oxygen Requirements

Because of the long retention period, the total amount of oxygen needed to biologically degrade animal and poultry wastes exceeds the

5-day biochemical oxygen demand (BOD_5) of the wastes. It more nearly equals the long-term or ultimate oxygen demand, BOD_u.

BOD_u of wastes is not commonly determined when making BOD tests. But chemical oxygen demand (COD) determinations are common. The COD of animal and poultry wastes is believed to be just slightly higher than BOD_u and can be used as a guide. Table 12-7 gives some realistic values of BOD_u for manure.

Table 12-7.--Ratio of ultimate BOD (BOD_u) of wastes to BOD_5

Waste	BOD_u to BOD_5
Dairy manure	3 to 5
Beef manure	2.5 to 4
Feeder swine manure	2 to 3
Breeder swine manure	3 to 4
Poultry manure	2 to 3
Domestic raw sewage	1.3 to 1.5

Oxygen requirement should be based on the maximum number and weight of animals contributing wastes to the lagoon. A design based on BOD_u is quite conservative and should provide total oxidation of organic wastes. For odor control and partial treatment a design based on 1.5 to 2.0 times BOD_5 is common.

Oxygen Transfer Rate

Surface aerators transfer oxygen from the atmosphere to the mixture of waste and water in the lagoon. Equipment manufacturers provide the transfer rate of their aerators on the basis of standard conditions--clear tap water at 20° C, at sea level, and no dissolved oxygen present.

In designing aerated lagoons the oxygen transfer rate under given field conditions must be determined. Odor is most likely to occur and dissolved oxygen to be low during summer when wastes degrade more rapidly. This is the period when the temperature of the liquid is at a maximum and the dissolved oxygen saturation capacity at its lowest. In practice it is best to evaluate the rate of oxygen transfer under the highest and lowest temperatures expected and use the lowest rate for design.

There are several formulas for computing field transfer rates for surface aerators. All are similar. The following is taken from a design manual by Aqua-Aerobic Systems, Inc., of Rockford, Illinois:

$$FTR = \frac{(CWTR)\ [(C_{dc})\ (B) - C_r]\ (1.024)^{T-20}\ \ (Alpha)}{C_{sc}}$$

where

FTR = field transfer rate (lb O_2/hp/hr)

CWTR = clean water transfer rate under standard conditions (sea level, DO = 0, 20° C) provided by manufacturer (lb O_2/hp/hr)

C_{dc} = saturation concentration of O_2 at design temperature and altitude (ppm)

$$B = \frac{\text{saturation concentration in waste water}}{\text{saturation concentration in clean water}}$$

C_r = residual concentration of O_2 to be maintained in lagoon (ppm)

T = design temperature (°C)

$$\text{Alpha} = \frac{\text{rate of } O_2 \text{ transfer in waste water}}{\text{rate of } O_2 \text{ transfer in clean water}}$$

C_{sc} = saturation concentration of O_2 in clean water at 20° C and sea level (ppm)

Figures 12-8 and 12-9 can be used to determine C_{dc}. The ratio B can be assumed as unity for aerated manure lagoon design. C_r, residual concentration of O_2, should be between 1 and 2. A value of C_r = 1.5 is recommended.

Figure 12-10 gives the numerical values for $(1.024)^{T-20}$ in the basic equation.

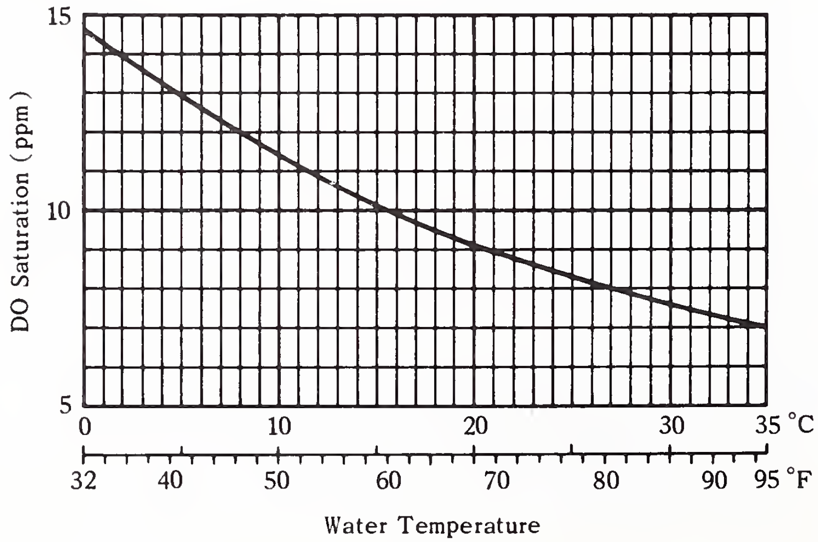


Figure 12-8.--Relation of dissolved oxygen saturation to water temperature (clean water at 20° C and sea level).

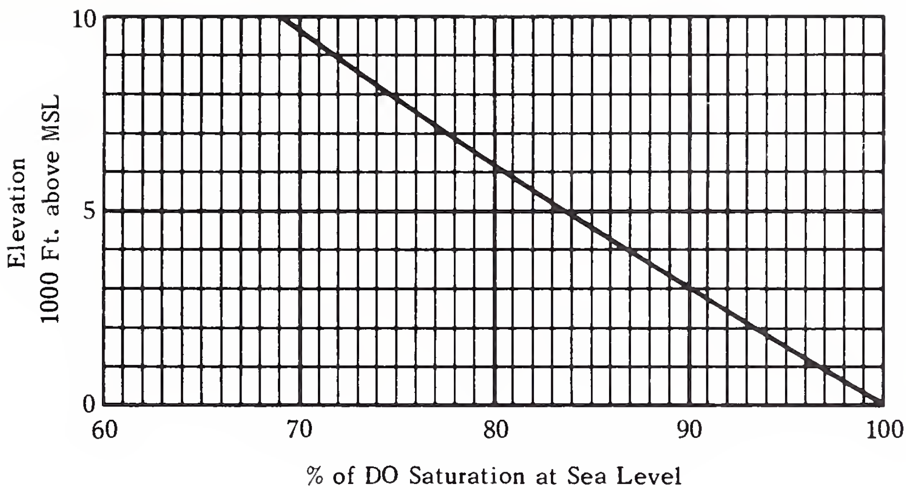


Figure 12-9.--Relation of dissolved oxygen saturation to elevation above sea level.

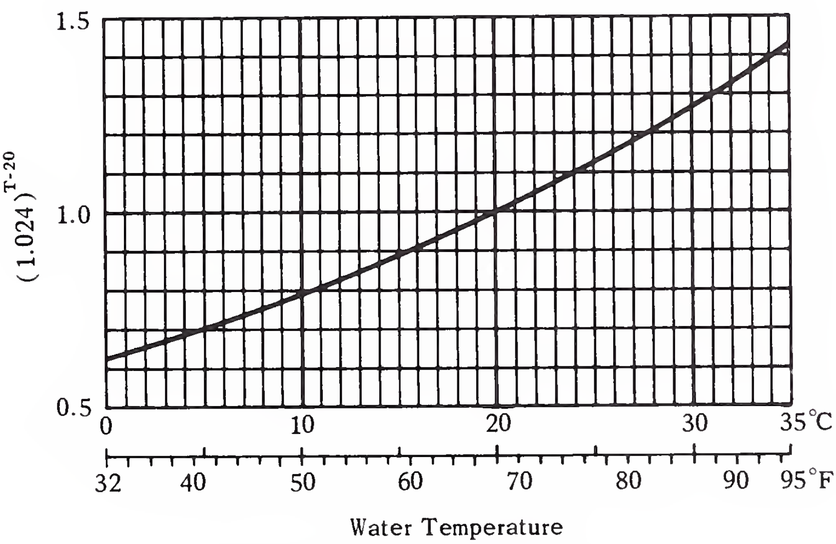


Figure 12-10.--Numerical values for $(1.024)^{T-20}$ at different temperatures.

The value of Alpha ranges from 0.5 to 1.3, depending on the type of waste. For domestic sewage it ranges from 0.85 to 0.95. A value of 0.75 for Alpha is recommended for design of aerated manure lagoons.

Using these recommended values, the basic FTR equation can be simplified to

$$FTR = \frac{CWTR\ (C_{dc} - 1.5)\ (1.024)^{T-20}}{12.2}$$

Horsepower Requirements for Oxygen Transfer

Aerator horsepower required for oxygen transfer in aerated lagoons designed for total oxidation can be determined by dividing BOD_u (lb/day) by FTR (lb O_2/hp/hr) times the number of hours per day aerators will operate.

$$hp = \frac{BOD_u}{FTR \times hrs/day}$$

A fully loaded aerated lagoon becomes anaerobic within a few hours (possibly minutes) if aeration is stopped. This is most critical when liquid temperature is higher than 7^{o} to 10^{o} C (45^{o} to 50^{o} F). Waste degradation and, therefore, oxygen demand are reduced at lower temperatures. It is best to operate aerators around the clock. It may be possible to reduce the number of aerators required during cold weather.

Surface aerators may become frozen in or damaged by ice if heating blankets are not used during extensive periods of below-freezing weather. Since biological degradation virtually ceases during such periods, odor is at a minimum, and it may be wise to cease aeration until ice cover disappears and biological activity resumes. Additional horsepower may be required to reestablish aerobic conditions in the lagoon.

Horsepower Requirements for Mixing

If surface aerators are used, it is important to provide enough agitation to disperse dissolved oxygen throughout the lagoon. It is not necessary to keep solids in total suspension, which requires substantially more horsepower.

Horsepower requirements for oxygen dispersion depends on aerator characteristics. Manufacturer's recommendations should be used in the final design. A general guide is 1 hp per 100,000 gal (13,300 ft^3) of lagoon volume.

In aerated lagoons for weak wastes such as domestic sewage, the horsepower required for oxygen dispersion often exceeds that required for oxygen transfer. In lagoons for animal manure the horsepower required for oxygen transfer usually controls, but the requirements for both oxygen dispersion and oxygen transfer should be checked.

Lagoon Dimensions

The optimum depth, width, and length of aerated lagoons are dictated by the characteristics of the aerator. Each model of aerator operates best within a limited range of depth. The number, size, and zones of influence of aerators have a direct relationship to the length and width of lagoon needed.

If the liquid depth of a lagoon is too shallow for the aerator selected, efficiency is lost and erosion results. If the liquid is too

deep for the aerators, draft tubes are needed to provide good circulation through the layers of liquid at the bottom.

Manufacturers usually provide basic data on proper range in depth and zone of influence for their various aerator models.

Costs

Costs for earthmoving, inlet and outlet facilities, seeding, and fencing of aerated lagoons are comparable to those for anaerobic lagoons.

Aerator costs vary by manufacturer and size of unit. Small units are more expensive on a horsepower basis than larger ones. Figure 12-11 can be used for a rough estimate of basic aerator and installed aerator costs on the basis of 1973 prices. Installed cost includes the aerator, anchor cables, electric cable, control panel, motor starter, and freight. A few large aerators are less expensive than several smaller ones. Final estimates should be based on equipment manufacturers' prices.

Estimates of operating costs must be based on the power requirements of the aerator and local power rates. Power costs generally range from $70 to $80 per horsepower per year on the basis of $0.01 per kilowatt hour.

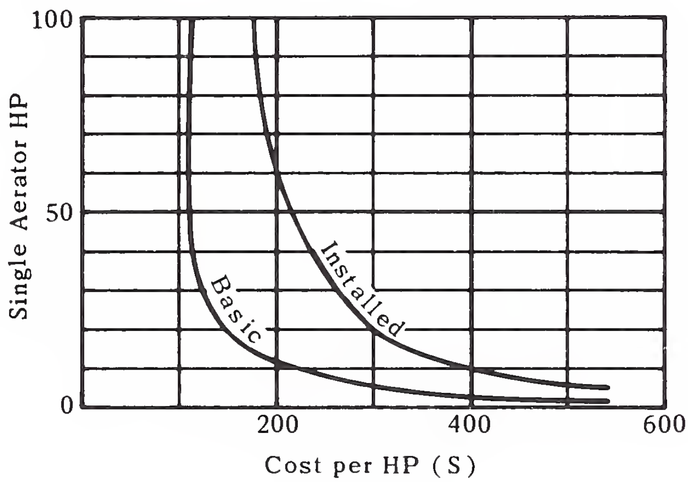


Figure 12-11.--Estimated cost of aerators (1973).

Design Example

Design a surface-aerated lagoon for a dairy enterprise with a maximum of 500 head, 1,200 lb each. All manure and wash water go to the lagoon, and outside runoff is diverted from the lagoon.

Given:

Manure production/1,200 lb dairy cow is 100 lb/day or 1.6 ft^3/day:

$$BOD_5 = 2\ lb/day$$

$$\text{Total solids} = 10\ lb/day$$

$$\text{Volatile solids} = 8\ lb/day$$

Wash water amounts to 2,000 gal/day:

$$BOD_5 = 50\ lb/day$$

$$\text{Total solids} = 80\ lb/day$$

$$\text{Volatile solids} = 60\ lb/day$$

Design winter temperature (liquid) is 41° F, 5° C
Design summer temperature (liquid) is 86° F, 30° C
Elevation is 1,500 ft msl
Rainfall is 45 inches (annual)
Evaporation is 30 inches (annual)

Lagoon volume:

Inflow:

$$500 \times 1.6\ ft^3/day + \frac{2{,}000\ gal}{7.5\ gal/ft^3} = 1{,}067\ ft^3/day$$

Detention (1 year):

$$365\ days \times 1{,}067\ ft^3/day = \underline{390{,}000\ ft^3}$$

Excess rainfall (assume 73,000 ft^2 surface area, 6-month drawdown):

$$\frac{15}{12}\ ft \times 73{,}000\ ft^2 \times 1/2 = \underline{45{,}600}\ ft^3$$
$$\text{Subtotal} = \underline{435{,}600}\ ft^3$$

Estimated sludge buildup (provide 3-yr storage):

$$VS/yr = 500 \times 8 \times 365 + 60 \times 365$$
$$= 4{,}060 \times 365 = 1{,}480{,}000\ lb/yr$$

$$\text{Sludge} = \frac{1{,}480{,}000\ lb/yr}{25\ lb/ft^3} = 59{,}200\ ft^3/yr$$
$$= 3 \times 59{,}200\ ft^3/yr = 177{,}600\ ft^3$$

$$\text{Total volume} = 435{,}600\ ft^3 + 177{,}600\ ft^3 = \underline{613{,}200\ ft^3}$$

<u>Ultimate BOD loading (BOD_u):</u>

$$BOD_5 \text{ loading} = 2 \text{ lb/head} \times 500 \text{ head} + 50 \text{ lb (wash water)}$$
$$= 1{,}050 \text{ lb/day}$$

$$BOD_u \text{ (table 12-6)} = 4 \times 1{,}050 \text{ lb } (BOD_5) = 4{,}200 \text{ lb/day}$$

<u>Field transfer rate:</u>

$$CWTR = 3.2 \text{ lb } O_2\text{/hp/hr (from manufacturer)}$$

$$FTR = \frac{CWTR\ (C_{dc}-1.5)\ (1.024)^{T-20}}{12.2}$$

Winter FTR (5° C, 1,500 ft msl):

$$C_{dc} = 12.8 \times 0.95 = 12.2 \text{ ppm (figs. 12-8 and 12-9)}$$

$$(1.024)^{T-20} = 0.70 \text{ (fig. 12-10)}$$

$$FTR \text{ (winter)} = \frac{3.2 \times 10.7 \times 0.70}{12.2} = 1.96 \quad \text{Say 2 lb } O_2\text{/hp/hr}$$

Summer FTR (30° C, 1,500 ft msl):

$$C_{dc} = 7.6 \times 0.95 = 7.2 \text{ ppm (figs. 12-8 and 12-9)}$$

$$(1.024)^{T-20} = 1.27 \text{ (figs. 12-10)}$$

$$FTR \text{ (summer)} = \frac{3.2 \times 5.7 \times 1.27}{12.2} = 1.90 \quad \text{Say 1.9 lb } O_2\text{/hp/hr (controls)}$$

<u>Horsepower required:</u>

For O_2 transfer:

$$hp = \frac{BOD_u}{FTR \times hr/day} = \frac{4{,}200}{1.9 \times 24} = 92.1 \text{ hp}$$

For O_2 dispersion:

$$hp = \frac{Vol(ft^3)}{13{,}300\ ft^3/hp} = \frac{613{,}200\ ft^3}{13{,}300} = 46.1 \text{ hp}$$

Horsepower required: <u>Use 100 hp</u>

<u>Dimensions of lagoon:</u>

Aerators = Use two rows of two 25-hp aerators per row

Volume = 613,200 ft^3

Depth = 10 ft (within manufacturer's recommendations for depth range)

Side slopes = 2 horizontal to 1 vertical

Bottom = 230 ft x 230 ft

Surface = 270 ft x 270 ft

Maximum dispersion distance is 96 ft by layout and 235 ft by manufacturer.

There should be some solids in suspension since agitation exceeds dispersion requirements. Sludge buildup is likely to be less than that used for design.

5. OXIDATION DITCHES

GENERAL

An oxidation ditch is worthy of consideration as another alternative to a naturally aerated lagoon. It is a shallow, continuous ditch, usually oval in layout, around which liquid wastes are circulated by a rotor that also transfers oxygen from the atmosphere to the liquid. Oxidation ditches have been used successfully for treating a wide variety of wastes, including domestic sewage and liquid manure. Oxidation ditches usually require less than 2 percent of the surface area required for aerobic lagoons and somewhat less than the surface area required for anaerobic lagoons used for treating the same wastes. The effluent from oxidation ditches that treat manure generally is not suitable for discharge to surface waters.

Because the technology relating to design and operation of oxidation ditches for livestock wastes is in its infancy, the following guidelines may be subject to substantial modification as experience is gained.

DESIGN

Oxidation Ditch Volume

The volume of oxidation ditches ranges from about 20 to 100 ft^3 per pound of BOD_5 maximum daily loading. In ditches treating livestock and poultry manure, it is suggested that at least 30 ft^3 be provided for each pound of BOD_5. If only the manure produced by livestock is added to an oxidation ditch with the suggested minimum volume, the retention period usually is 30 to 70 days.

Actual retention periods are somewhat shorter because it is necessary to add water to offset evaporation and to maintain the solids concentration below certain maximum levels.

With loading at the rate of 1 lb BOD_5/30 ft^3, the retention periods for oxidation ditches treating various wastes are probably

about 20 to 30 days for swine wastes, 15 to 20 days for beef and dairy cattle wastes, and 10 to 15 days for poultry wastes.

Solids Buildup

As manure is added to an oxidation ditch, there is a gradual buildup of solids in the liquid. It is necessary to trap and remove solids occasionally or to replace part of the concentrated liquid with water.

Studies indicate that oxidation ditches operate best when the concentration of solids is more than 2,000 mg/l. Recommendations for the maximum concentration range from 20,000 to 60,000 mg/l. A maximum concentration of 50,000 mg/l appears reasonable for keeping solids in suspension and for pumping to storage or land disposal sites.

Storage facilities often are required for the sludge and concentrated liquid drawn from the oxidation ditch until the effluent can be safely applied to land. The treated effluent usually has a significant oxygen demand and may require aeration to avoid odor.

Oxygen Requirements

Without a good estimate of the retention period for wastes in an oxidation ditch it is difficult to estimate the oxygen required. But for a retention period of 10 to 30 days (rough figure) the oxygen requirement is more than the BOD_5 but less than the BOD_u. Experience indicates that providing oxygen to satisfy twice the BOD_5 generally maintains aerobic conditions and satisfactory functioning within the ditch.

Oxygen requirements should be based on the maximum number and weight of livestock contributing to the oxidation ditch. Local research data or onsite measurements of BOD_5 should be used if available. If local data are lacking, the information in table 4-1 of this manual or in table 1, Composition of livestock and poultry wastes, of National Engineering Standard 359 can be used as a guide.

Oxygen Transfer Rate

Rotors transfer oxygen from the atmosphere to the liquid in the oxidation ditch. The rate of transfer varies by type of rotor and its length, immersion depth, and speed. Rotor manufacturers provide tables or graphs showing the oxygen transfer rate per foot of rotor at various immersion depths and rotor speeds. The rate is usually determined for clear water with no dissolved oxygen at 20° C at sea level.

An example of such a graph is figure 12-12, which was published by Lakeside Equipment Corporation of Bartlett, Ill., for its 27-1/2-inch cage rotor. This particular rotor appears to have a high oxygenation capacity. Test data for the specific rotors being used should be used in designing an oxidation ditch.

The oxygen transfer rate under given conditions must be determined to design an oxidation ditch. Although several abbreviated formulas are available for computing field transfer rates, many make assumptions

that may be valid only under certain limited conditions, e.g., municipal sewage, and may not be accurate when applied to manure ditches. It is best to start with a fundamental formula that includes all the main variables to be considered. The following formula from a design manual by Aqua-Aerobic System, Inc., of Rockford, Ill., has been modified to apply to oxidation ditch rotors.

$$\text{FTR} = \frac{(\text{CWTR})\ [(C_{dc})\ (B) - C_r]\ (1.024)^{T-20}\ (\text{Alpha})}{C_{sc}}$$

where

FTR = field transfer rate (lb O_2/hr/ft of rotor)

CWTR = clean water transfer rate under standard conditions (sea level, DO = 0, 20° C) provided by manufacturer (lb O_2/hr/ft of rotor)

C_{dc} = saturation concentration of O_2 at design temperature and altitude (ppm).

$B = \dfrac{\text{saturation concentration in waste water}}{\text{saturation concentration in clean water}}$

C_r = residual O_2 concentration to be maintained in ditch (ppm)

T = design temperature (°C)

$\text{Alpha} = \dfrac{\text{rate of } O_2 \text{ transfer in waste water}}{\text{rate of } O_2 \text{ transfer in clean water}}$

C_{sc} = saturation concentration in clean water at sea level (ppm)

Use figures 12-8 and 12-9 to determine C_{dc}. The ratio B can be assumed as unity for oxidation ditch design. C_r should be about 0.5 ppm. In an oxidation ditch the dissolved oxygen is greatest in the liquid immediately behind the rotor and least in the liquid just ahead of it. A C_r value of 0.5 is recommended because it represents the lowest dissolved oxygen level to be expected in the ditch system.

Figure 12-10 gives values for $(1.024)^{T-20}$ in the basic equation.

The value of Alpha ranges from 0.5 to 1.3, depending on the type of waste. For domestic sewage it ranges from 0.85 to 0.95. Using Alpha = 0.75 is recommended for designing manure oxidation ditches.

If these recommended values are used, the basic FTR equation can be simplified to:

$$\text{FTR} = \frac{\text{CWTR}\ (C_{dc} - 0.5)\ (1.024)^{T-20}}{12.2}$$

Length of Rotor for Oxygen Transfer

Oxygen transfer rates vary with rotor speed, immersion, and length--the greater the speed or immersion, the greater the rate of transfer. This allows considerable latitude in the design and operation of an oxidation ditch.

Rotors are designed to operate at speeds of 60 to 120 rpm or more and immersion depths of 2 to 12 inches. It is suggested that actual oxidation ditch design be based on values in the intermediate range of manufacturers' recommendations for speed and immersion depth. For oxidation ditches for livestock manure a speed of about 100 rpm and an immersion depth of about 6 inches have been quite satisfactory.

FTR for field conditions at the site can be computed by using the CWTR test data provided by the manufacturer for the selected rotor speed and immersion depth.

$$FTR = \frac{CWTR\ (C_{dc} - 0.5)\ (1.024)^{T-20}}{12.2}$$

The length of rotor required for oxygen transfer can then be determined by dividing 2 x BOD_5 (lb/O_2/day) by FTR (lb/O_2/hr/ft of rotor) times hours per day rotor will operate (24 hours/day).

$$\text{Rotor length} = \frac{2 \times BOD_5}{24 \times FTR}$$

It is necessary to operate the rotor around the clock to avoid septic conditions in the ditch and to prevent settling of solids.

Rotor Pumping Requirements

Circulation around an oxidation ditch results from the push imposed by the rotor, often referred to as the rotor pumping capacity. Pumping capacity generally increases with rotor speed and immersion depth.

The pumping capacity of rotors for various speed and immersions is not so readily available as the oxygen transfer rate. One manufacturer recommends that the liquid volume of an oxidation ditch not exceed 16,000 gal per foot of rotor. Bulletin 737, Aerobic Treatment of Livestock Wastes, published by the University of Illinois, Urbana, Ill., in May 1970, gives information on the pumping capacity of a 27-1/2-in. cage rotor operating at 100 rpm that indicates that the pumping capacity in cubic feet per second per foot of rotor equals 0.57 cfs per inch of rotor immersion. This was calculated for a total ditch length (rotor to rotor) of 300 ft.

There are few published data on the relation of rotor speed to pumping capacity, but it appears that the relationship is generally a fairly straight line for rotor speeds of 60 to 120 rpm. For lack of a better basis, it is suggested that pumping capacity for a rotor at speeds other than 100 rpm be estimated as:

Pumping capacity (ft^3/sec/ft)

$$= 0.57 \times \text{immersion depth (in.)} \times \frac{\text{operating speed (rpm)}}{100}$$

Ditch velocity will then be the pumping capacity in cubic feet per second per foot of rotor times rotor length in feet divided by the liquid cross-section area in square feet.

Oxidation Ditch Dimensions

Many factors must be considered in selecting the most desirable dimensions for an oxidation ditch:

1. The ditch may be rectangular or trapezoidal in cross section and lined or unlined. Rectangular lined ditches are most common. Trapezoidal lined ditches also function satisfactorily. Unlined ditches may be suitable in impervious soils in which scouring at ditch velocities will not be a problem. In unlined ditches the soil adjacent to rotors and on curves may need protection against erosion, and about 20 percent additional pumping capacity may be required to offset the additional channel friction.
2. The ditch cross section times length must provide at least the volume determined by BOD_5 loading.
3. The ditch bottom width should not be more than 1.5 times the maximum immersed rotor length as determined by oxygen transfer and pumping capacity.
4. The maximum distance around the ditch or between rotors should be limited to 300 to 350 feet.
5. The liquid depth should not be more than four times the rotor immersion depth to minimize deposition of solids. This generally limits the depth to about 24 in. for manure ditches.
6. A minimum velocity of 1.25 fps is recommended for oxidation ditches treating manure. Velocities more than 2.5 fps reduce the rate of oxygen transfer at the rotor.
7. A freeboard of at least 1 ft between the liquid surface and the top of the ditch should be provided to allow adjustment of level of operation and to contain froth or foam that occurs under some conditions.
8. The building layout may have considerable influence on the dimensions of oxidation ditches in buildings.
9. Most oxidation ditches are oval or circular, but the shape varies according to site limitations. Sharp curves should be kept to a minimum to maintain the velocity as nearly constant as possible within the cross section.

COSTS

Capital costs for an oxidation ditch include ditch construction plus rotor and installation costs. Construction cost for the ditch can be estimated readily by using the conventional cost-estimating procedures associated with earthmoving, materials, and labor. Estimated costs for rotors and appurtenances, which vary by make and size, can be determined only from a manufacturer or his sales representative. As a rough guide, rotors, including motors, drives, and installation, will

probably cost \$250 to \$450 per foot of rotor on the basis of 1973 prices.

Most manufacturers provide data on the power required for operating their rotors. Figure 12-12 shows the power required in kilowatts per foot of rotor for the 27-1/2-in rotor supplied by Lakeside Equipment Corporation. Other manufacturers also provide data on kilowatt or horsepower requirements.

Both kilowatts (kW) and horsepower can be converted readily to kilowatthours (kWh) per day, month, or year, from which operating costs can be computed based on power rates. The conversion factor is 1 hp = 0.746 kW.

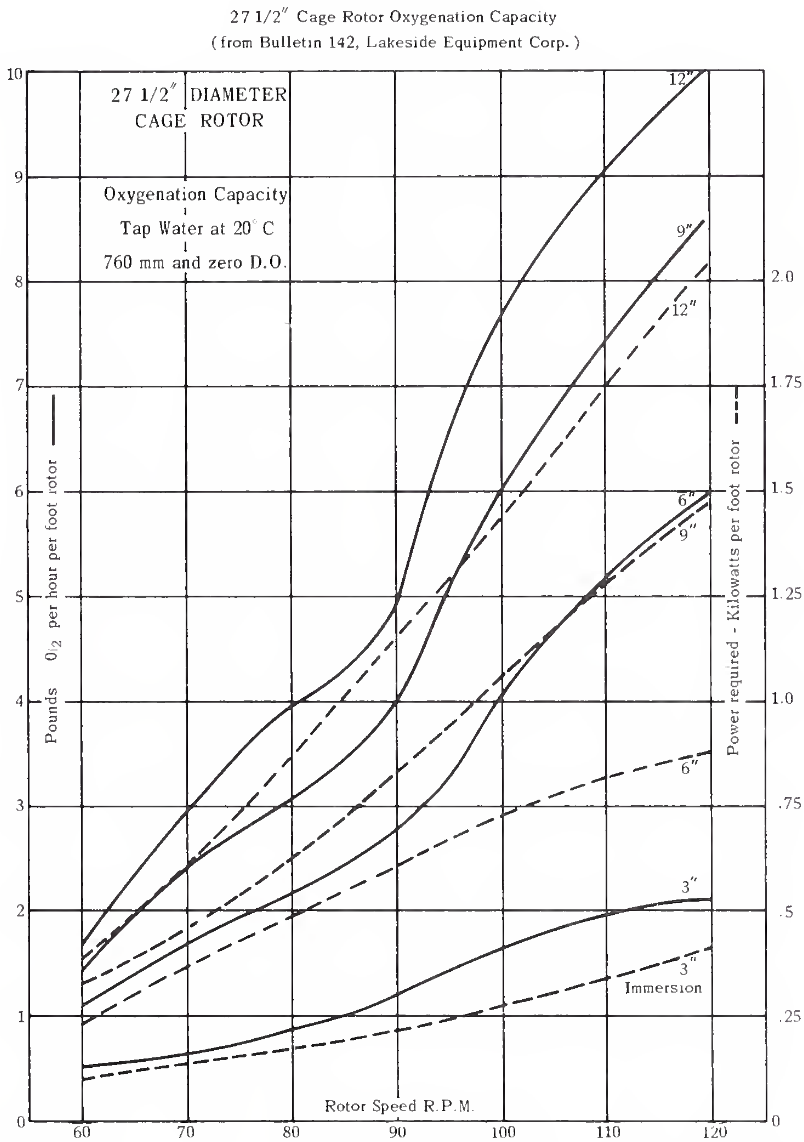


Figure 12-12.--Oxygenation capacity of 27-1/2-in cage rotor (from Bulletin 142, Lakeside Equipment Corporation).

Limited experience with manure oxidation ditches to date indicates that rotor costs range from $10 to $30 per lb of BOD_5, and power costs (based on $0.02/kWh) range from $0.015 to $0.025 per day per lb of BOD_5.

NOTES ON OPERATION

An oxidation ditch can reduce BOD_5 by 90 percent or more. The reductions usually are higher in summer than in winter in northern areas. Experience indicates that oxidation ditches continue to operate satisfactorily in subfreezing temperatures if the rotor and about 25 percent of the ditch are housed.

For a number of years oxidation ditches treating municipal sewage have operated successfully completely exposed to the weather in northern areas of the United States and Canada.

Good ventilation must be provided above an oxidation ditch within a building to protect animals and human beings from accumulation of dangerous gases. This is particularly important if the liquid has become septic because of rotor failure or overloading. If the liquid becomes septic, it is recommended that about half of the ditch contents be withdrawn and replaced with water and that animals and human beings be removed from the building when the rotor is again put into operation.

Some foaming can be expected at startup of an oxidation ditch. The foaming should decrease within a few weeks when the microbial population is well established. Use of antifoam agents such as oil or other commercial products can help control foaming. Foaming may also result from overloading the ditch.

Along with solids a buildup of salts can be expected in the ditch. Removal of part of the ditch contents and replacement with water reduces both solids and salt levels.

Most operators seem to prefer a continuous overflow oxidation ditch that requires less adjustment of rotor elevations. Overflow to holding tanks or lagoons is common.

The oxidation ditch should be filled with water to the operating level and wastes added gradually for several days during startup. Startup should begin during warm weather when liquid temperatures are above 55° F to facilitate development of a good quality floc.

DESIGN EXAMPLE

Design an oxidation ditch for a dairy farm with a maximum of 200 head, each weighing 1,200 lb. All manure and wash water go to the oxidation ditch. There are no unreasonable space limitations, and it can be assumed that the rotor and about 25 percent of the ditch will be housed.

Given:

Manure production per 1,200 lb dairy cow:

Manure = 100 lb/day or 1.6 ft^3/day

BOD_5 = 2 lb/day

Wash water:
Volume = 1,000 gal/day
BOD_5 = 20 lb/day
Design temperatures (liquid):
Winter = 5° C
Summer = 30° C
Elevation: 2,000 ft msl

Ditch volume ($30\ ft^3/lb\ BOD_5$):

Daily BOD_5:
2 lb/head x 200 head = 400 lb
Wash water = 20 lb
Total = 420 lb

$$\text{Volume} = 420\ lb\ BOD_5 \times 30\ ft^3/lb = 12{,}600\ ft^3$$

Oxygen requirements:

$$O_2 = 2 \times BOD_5 = 840\ lb/day$$

Oxygen transfer rate:

Assume 27-1/2-in. cage rotor similar to that in fig. 12-12, rotor immersion of 6 in. and rotor speed of 100 rpm. Oxygenation capacity (tap water at sea level and 20° C) is 4.0 lb O_2/hr/ft of rotor.

Field transfer rate (winter):

$$FTR = \frac{CWTR\ (C_{dc} - 0.5)\ (1.024)^{T-20}}{12.2}$$

$$CWTR = 4\ lb/hr/ft\ \text{(fig. 12-12)}$$

$$C_{dc} = 12.8 \times 0.93 = 11.9\ ppm\ \text{(figs. 12-8 and 12-9)}$$

$$(1.024)^{T-20} = 0.70\ \text{(fig. 12-10)}$$

$$FTR = \frac{4.0\ (11.9 - 0.5)\ 0.7}{12.2} = 2.6\ lb\ O_2/hr/ft$$

Field transfer rate (summer):

$$C_{dc} = 7.6 \times 0.93 = 7.1\ \text{(figs. 12-8 and 12-9)}$$

$$(1.024)^{T-20} = 1.27\ \text{(fig. 12-10)}$$

$$FTR = \frac{4.0\ (7.1 - 0.5)\ 1.27}{12.2}\ 2.7$$

Winter transfer rate controls; use 2.6 lb O_2/hr/ft

Rotor length required for oxygen transfer:

$$\text{Length} = \frac{2 \times BOD_5}{24\ FTR} = \frac{840}{24 \times 2.6} = 13.5 \text{ ft}$$

Ditch dimensions:

Try several widths of ditch and several lengths and locations for rotor to get best combination. Try two 8-ft rotors side by side, 6-in. immersion.

$$\text{Depth} = 4 \times 6 \text{ in. immersion} = 2 \text{ ft}$$

Width (provide 1 ft on each side and 2 ft between rotors)

$$\text{Width} = 8 \text{ ft} + 8 \text{ ft} + 4 \text{ ft} = 20 \text{ ft (less than } 1.5 \times \text{rotor length)}$$

$$\text{Area (rectangular ditch)} = 20 \text{ ft} \times 2 = 40 \text{ ft}^2$$

$$\text{Length} = \frac{\text{Volume}}{\text{area}} = \frac{12{,}600 \text{ ft}^3}{40 \text{ ft}^2} = 315 \text{ ft}$$

Check ditch velocity:

$$\text{Pumping capacity} = 0.57 \times \text{immersion} \times \frac{\text{operating speed}}{100}$$

$$= 0.57 \times 6 \times 1 = 3.42 \text{ ft}^3\text{/ft of rotor}$$

$$\text{Velocity} = \frac{\text{pumping capacity} \times \text{rotor length}}{\text{ditch area}}$$

$$= \frac{3.42 \times 16}{16} = 1.37 \text{ ft/sec}$$

Motor horsepower:

Kilowatts per foot of rotor = 0.725 (fig. 12-12)

$$\text{Horsepower required} = \frac{0.725 \text{ kW/ft} \times 16 \text{ ft}}{0.746 \text{ kW/hp}} = 15.6 \text{ hp}$$

Use 20-hp motor

PART V - CONSERVATION PRACTICES FOR WASTE MANAGEMENT

1. INTRODUCTION

Conservation practices for water management and erosion control developed through years of experience and use on agricultural land by farmers and conservationists are useful components of waste management systems. Engineering conservation practice standards and specification guides along with field manuals and engineering handbooks provide guidance for planning, designing, constructing, and maintaining these practices.

This section briefly explains these practices and supplements the data and criteria in existing standards and handbooks for application to waste management systems. The existing data along with this supplemental information should provide adequate guidelines for these practices. As more experience and research become available, some changes in design may be desirable.

2. GENERAL

Any uncontrolled runoff from rain that falls on feedlots or other open areas of concentrated wastes may carry pollution from the facility to lakes or streams. Unpolluted runoff from outside the waste area that enters the area becomes polluted. Many conservation practices are suitable for preventing pollution of clean water and for regulating, intercepting, and recycling polluted water and wastes.

Poorly drained disposal areas with a high water table are of limited use unless they are properly drained by a subsurface drainage system, making the soil more suitable for disposal and cycling of effluents. Disposal areas on steep land may be subject to sheet erosion from rainfall runoff unless erosion control practices are used. A waste management system is not complete until all its components, from interception to final disposal, are installed and functioning.

3. DEFINITIONS OF TYPICAL PRACTICES

Definitions of conservation practices commonly used with waste management systems follow. Other practices and their definitions are given in section 2 of the National Engineering Handbook and in the National Handbook of Conservation Practices. Typical cross sections for some practices are shown in figure 12-13. Other shapes and forms can be used where appropriate.

GRASSED WATERWAY OR OUTLET

A natural or constructed waterway or outlet shaped or graded and established in suitable vegetation as needed for the safe disposal of runoff from a field, diversions, terraces, or other structures.

DIVERSION

A channel with a supporting ridge on the lower side constructed across the slope.

DRAINAGE FIELD DITCH

A graded ditch for collecting excess water within a field.

TERRACE

An earth embankment or a ridge and channel constructed across the slope at a suitable spacing and grade. Terraces may be basin, gradient, level, or parallel, depending on design details.

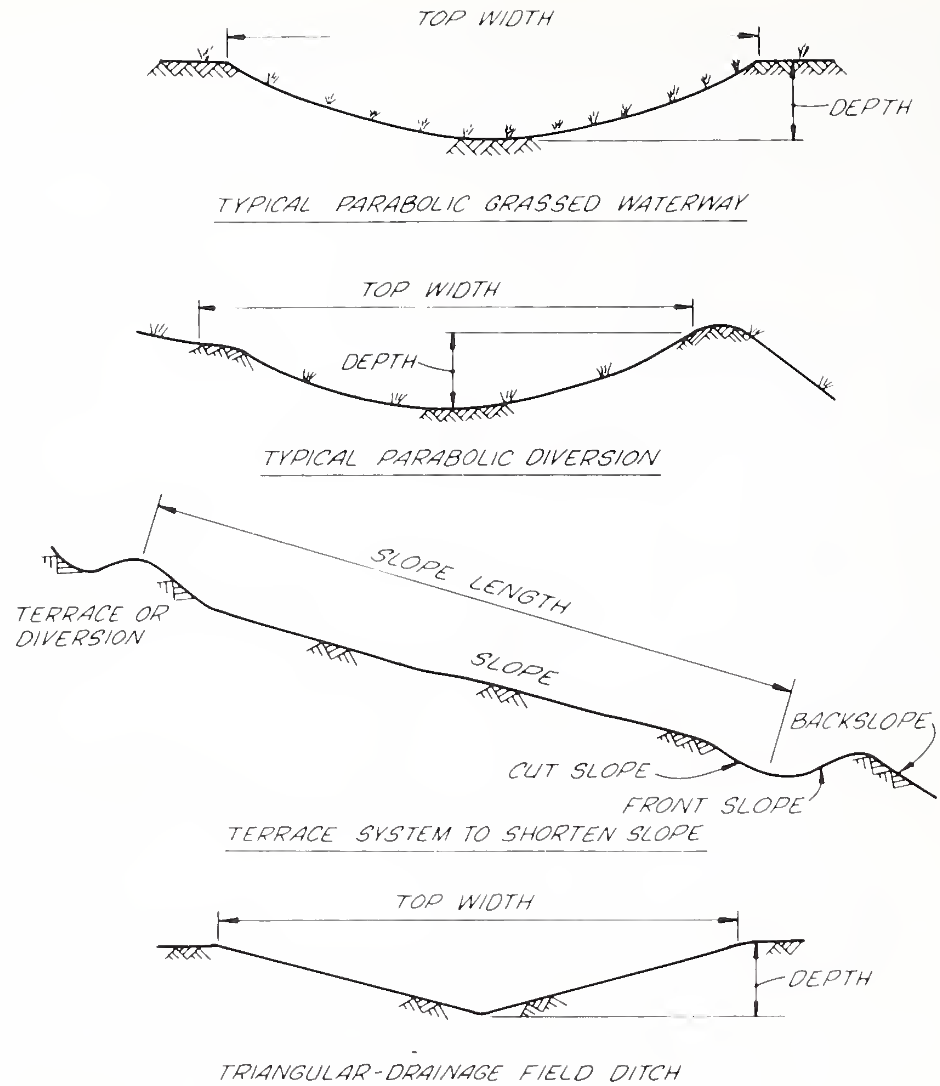


Figure 12-13.--Cross sections of typical practices.

SUBSURFACE DRAINS

A conduit such as tile, pipe, or tubing installed beneath the ground surface to collect and/or convey drainage water.

DRAINAGE LAND GRADING

Reshaping the surface of land to be drained to a planned grade.

STRUCTURE FOR WATER CONTROL

A structure in an irrigation or drainage system or channel for water management that conveys water, controls the direction or rate of flow, or maintains a desired water-surface elevation in a natural or artificial channel.

GRADE STABILIZATION STRUCTURE

A structure to stabilize the grade or to control head cutting in natural or artificial channels.

4. APPLICATION OF PRACTICES

The practices (structures) can be channels, conduits, or other water-control structures that can be used in planning systems that convey, collect, or divert either clean water or water carrying waste materials. Except for conveying clean water in and around municipal sewage systems and sanitary landfills, earth channels usually are only for water carrying waste material from agricultural facilities in rural areas. Laws and regulations usually require that many waste management systems be located some distance from neighbors or communities.

Channel systems and other water-control measures must have adequate capacity and must also be stable enough to prevent excessive erosion. They must provide either transport or settling of solids. They must be installed so that they operate satisfactorily and require only a reasonable amount of maintenance.

Control of sheet erosion on earth lots and on land disposal areas for liquid waste is essential for their sustained use in waste management systems. Diversions, terraces, land grading, and other supporting measures should be used on areas needing protection.

Land disposal areas may also be wet and require drainage for satisfactory use. Subsurface and surface drainage and land grading may increase the suitability of some sites for recycling and assimilating waste material.

5. STANDARDS AND SPECIFICATIONS

The minimum level of design for any component of a waste management system should meet the criteria for the level of protection required for the most stringent pollution-abatement practice. For example, if a holding pond is designed on the basis of controlling runoff from a 25-year, 24-hour storm, a diversion used as part of the waste management system should be designed on the same basis.

State standards in technical guides should meet or exceed national standards and conform to federal, state, or local laws and regulations for the waste management system.

Procedures for surveys, design, construction, and maintenance are in the Engineering Field Manual and may be supplemented in technical notes or other guides.

6. CHARACTERISTICS OF RUNOFF

WATERSHED RUNOFF

Charts and procedures for designing channels and water-control systems are usually based on carrying runoff from watersheds in farm crops or other vegetative cover or from impervious areas such as

concrete or building roofs. This runoff may be clear, or it may carry sediment and debris reflecting the characteristics of the watershed. Most charts and aids are for designing channels and water-control structures that carry clear water or water with some sediment.

Special designs and additional considerations are required for runoff carrying a heavy load of debris or sediment.

FROM WASTE MANAGEMENT SYSTEMS

The rain that falls on areas covered with waste materials carries some of the waste with it as runoff occurs. The characteristics of the waste and the surface of the area influence the design of the conservation practices for diverting or controlling this waste-laden runoff.

Earth Lots

Runoff from open earth feedlots may contain feces and feed in addition to sediment and debris. The surface of these lots is trampled by stock and is usually bare. Because soil permeability on most lots is low, a runoff curve number of about 90 or 91 seems realistic.

Paved Lots

Runoff from paved lots, usually concrete but sometimes asphalt or other hard materials, is not charged with sediment. It may carry bedding of straw or other material in addition to the feces and feed. The runoff curve number for paved lots is higher than for earth lots and is usually assumed to be about 94 or 95.

Other Systems

Runoff of clear water combined with waste-laden water from paved or bare lots may have to be considered as well as runoff from flushing systems. In some areas chutes and dikes can be used to transport or contain semisolid or solid manure. Chutes and dikes are usually components of holding ponds or manure-stacking facilities.

FLOW AND OTHER CHARACTERISTICS

Liquid livestock manure with moisture content of at least 85 percent and without bedding will flow in a deep horizontal gutter. At 90 percent moisture content the manure can be easily pumped. Manure that contains at least 8 percent bedding is usually considered solid manure. Some bedding materials are difficult to move in shallow low-capacity channels that may be used for animal waste. If long straw is used for bedding, flow is slow if the straw content of the manure is 2 percent.

Runoff from precipitation on open lots produces a complex mixture of water and solids that may have a very low solids content or that may be near the consistency of fresh manure. The percentage of solids in runoff varies with precipitation and watershed factors and with the management and type of treatment on the lot. The percentage of solids

also varies throughout a storm, ranging from 0.2 percent to possibly 2 or 3 percent.

7. CLEAN-WATER CARRYING PRACTICES

In contrast to municipal sewage where much water is added to the waste material, animal waste systems are usually designed to add only a minimum amount of water for conveyance. This reduces the labor and cost of collection, storage, and disposal. To reduce the amount of water combining with the waste, grass waterways, diversions, and other practices are used to keep outside clean water from the area of the waste management system.

Figure 12-14 shows typical methods of locating conservation practices for diversion of clean water. The water that usually flows into and across the lot has been collected by a diversion. The diversion empties into a grassed waterway that carries the clean-water runoff to a natural outlet. A diversion has also been constructed above the holding pond to keep clean water from entering the pond and also empties into a waterway that conveys the water to the natural outlet. Clean water can be kept from a waste source and management system in numerous ways. Each waste management system requires special design and layout.

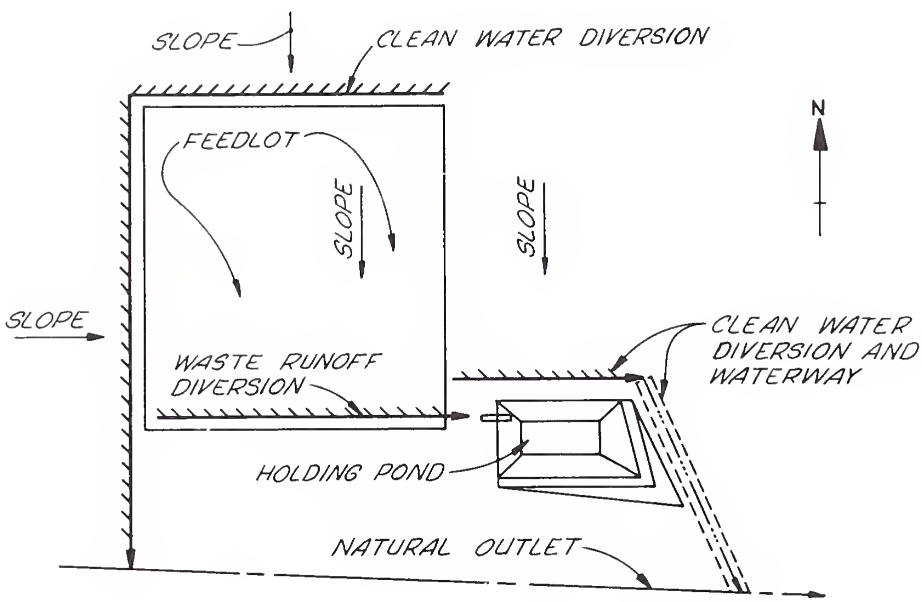


Figure 12-14.--Typical location of diversions.

In some locations the disposal area can be made more useful and the risk of pollution from runoff can be reduced by using conservation practices. Figure 12-15 shows a disposal area from which the clean water from higher ground that usually floods the area has been diverted and collected in a waterway.

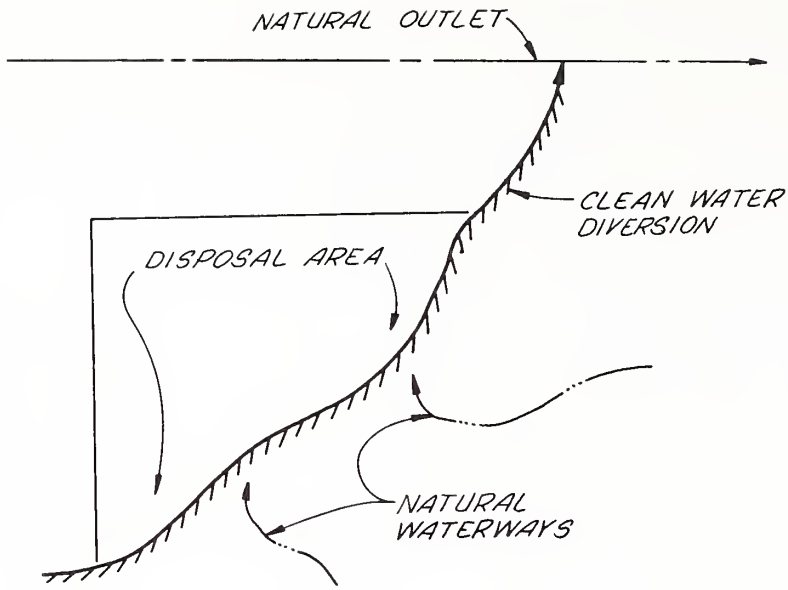


Figure 12-15.--Diversion used to protect a disposal area.

Municipal waste system areas subjected to runoff from outside areas can also be protected by conservation practices that improve water management and access and reduce maintenance.

8. WASTE-WATER CARRYING PRACTICES

Runoff containing waste materials can be collected by properly designed conservation practices. The closer the practice is to the facility, waste source, and holding system, the fewer the problems. Usually these practices for collection, conveyance, or diversion are limited to livestock areas that are subject to runoff from precipitation. But they can sometimes be used as components of confined-livestock waste management systems or of systems for land application of effluents from food processing and municipal waste treatment plants.

These practices can be located in or outside the lot or facilities. Those in lots are subject to damage by livestock. Available land and construction or maintenance equipment must also be considered when planning practices.

Figure 12-16 shows a typical feedlot system using a diversion inside the lot to collect the runoff. The ridge of the diversion is located under the south fence of the lot. The diversion is also used as a settling basin for solids. The basin empties into the holding pond through a structure for water control. The location within the lot makes it impossible to grow vegetation on the channels, and the bottom of the channel may stay wet for long periods.

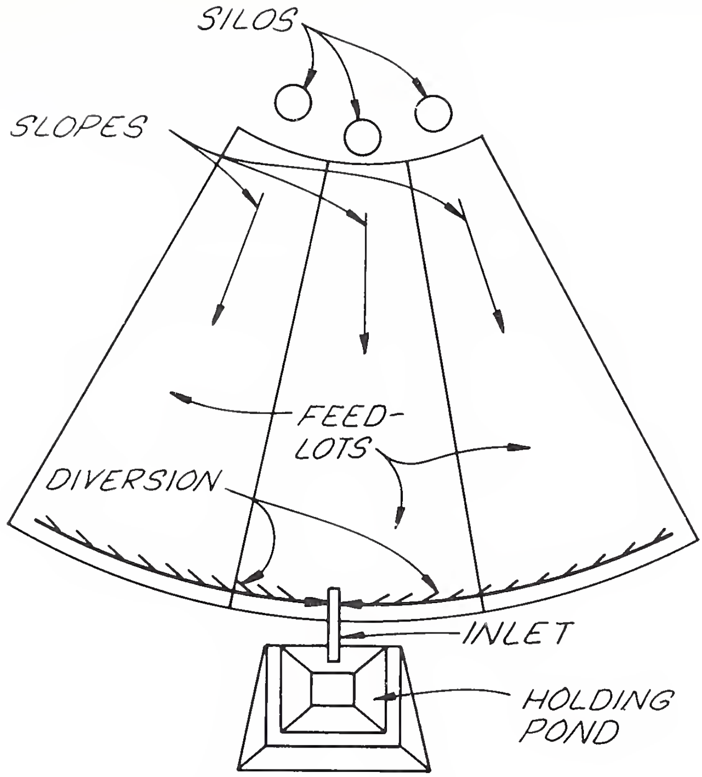


Figure 12-16.--Diversion inside feedlot.

A diversion can be placed outside the lot as shown in figure 12-17. In this layout the runoff must filter through the fences to enter the diversion. The fenceline and diversion may be subject to accumulation of waste material. In many designs the diversion for waste-laden runoff is used as a settling basin.

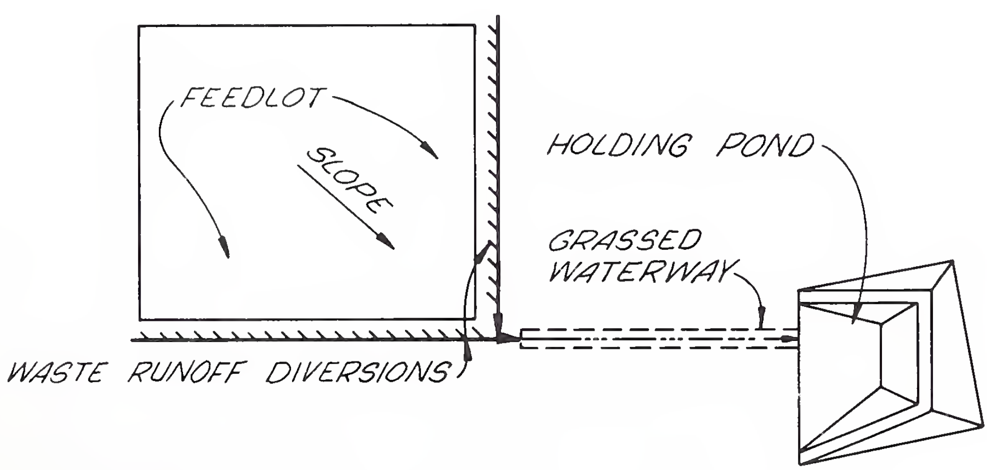


Figure 12-17.--Diversion outside feedlot.

Terraces may be necessary on steep disposal areas to prevent soil erosion from natural rainfall or runoff of wastes accumulated in waterways that may eventually pollute streams. Figure 12-18 shows a typical parallel-terrace system with tile outlets that is well suited to sloping disposal sites.

9. PLANNING, DESIGN, CONSTRUCTION, AND MAINTENANCE

This section discusses references, available handbook data, and other supplemental data for designing conservation practices used for waste management systems. SCS national handbooks, especially the Engineering Field Manual, Drainage of Agricultural Lands (NEH-16), and Irrigation (NEH-15) are useful additional guides for planning and construction.

SURVEYS

Installation of livestock, poultry, and other waste management systems often changes the surface drainage pattern to accommodate the facility and its components.

It is necessary to know the location of feeding bunks, buildings, and storage and loading areas as well as the operating procedure before a final layout of conservation practices can be made. Some drainage areas can be located on aerial photos, but many areas served are so small that field surveys may need to be made for locating and designing the practices.

Soil maps and logs are needed to determine design parameters and applicability of the practice to the waste management system and site conditions.

Outlets for spillways and channel systems carrying clean water must be located. If subsurface drainage is considered, an outlet with adequate depth must be located.

Profiles, cross sections, and topography should be in enough detail to determine the dimensions and slope of the practice and to estimate construction details and cost.

DISCHARGES

The discharge from the watershed or lot and the required capacity for channels and other structures can be determined by procedures given in chapter 2 of the Engineering Field Manual.

CHANNEL SYSTEMS

The design for all practices should be compatible with the livestock, poultry, or other waste management system and final waste disposal. The level of protection provided for the conservation practices should be equal to that provided for other components of the pollution-abatement system to protect the integrity of the total system.

Either vegetated or bare earth channels can be used as components of waste management systems, depending on climatic conditions and

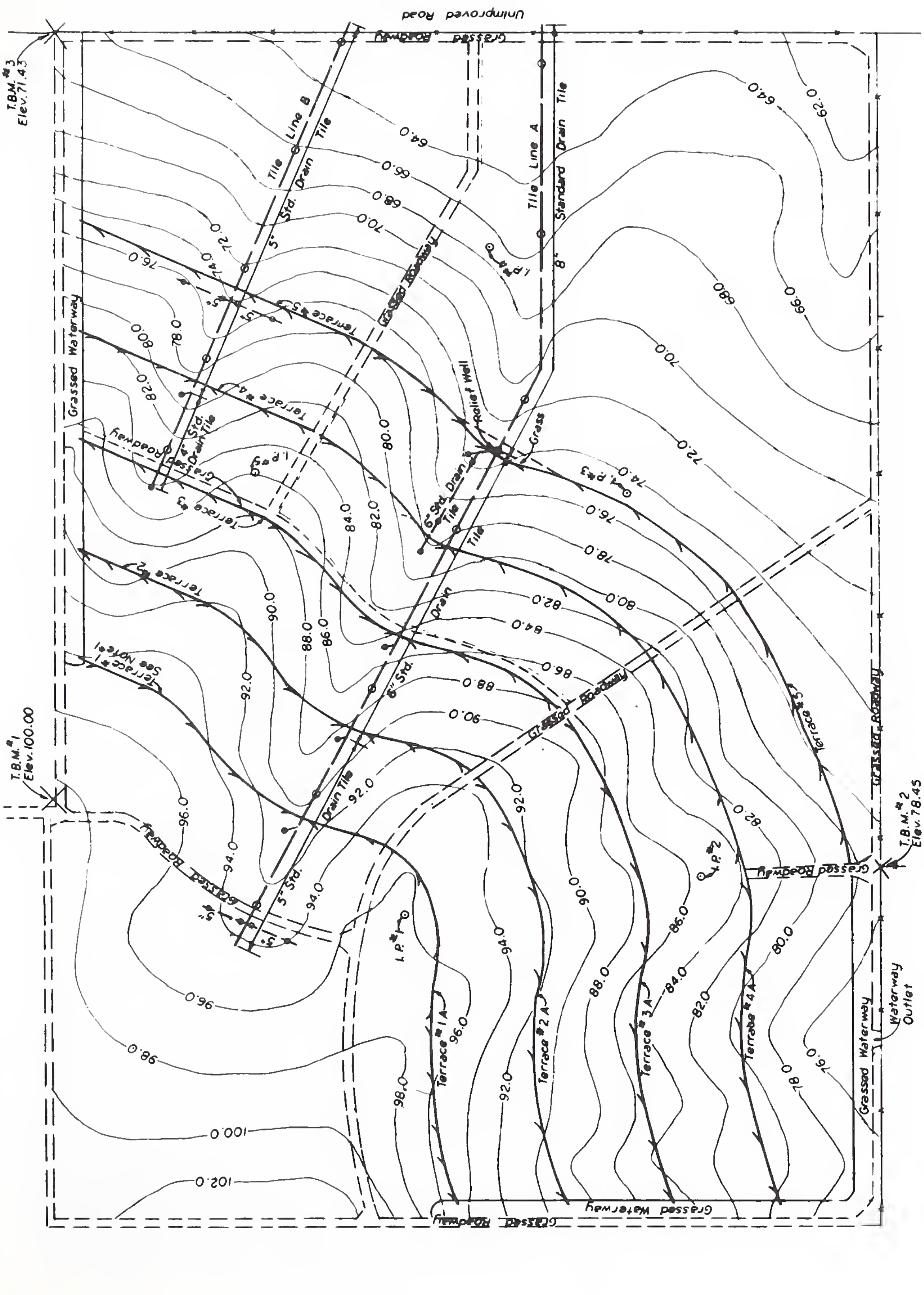


Figure 12-18.--Parallel terrace system.

whether they are intended for heavy or light use. Concrete or lined channels may be required if slopes are steep or if high velocities are anticipated. Chapters 7, 8, 9, and 14 of the Engineering Field Manual provide guidance on vegetal retardance factors, permissible velocities, and other design parameters.

10. SHEET-EROSION CONTROL SYSTEMS

Waste management or disposal systems on steep sites may be subject to sheet erosion or gully erosion from runoff. Properly located and designed channel systems, as discussed in the previous section, prevent erosion along drainageways. The amount of sheet erosion depends on the length of slope and other factors given in the Universal Soil Loss Equation.

Diversions and terrace systems can be used on sloping land to make it suitable for livestock facilities or waste disposal sites.

Parallel terraces with underground outlets, which eliminate the necessity for point rows and waterways, are suited to modern farming. Figure 12-19 shows a well-planned terrace system suitable for a steep disposal site.

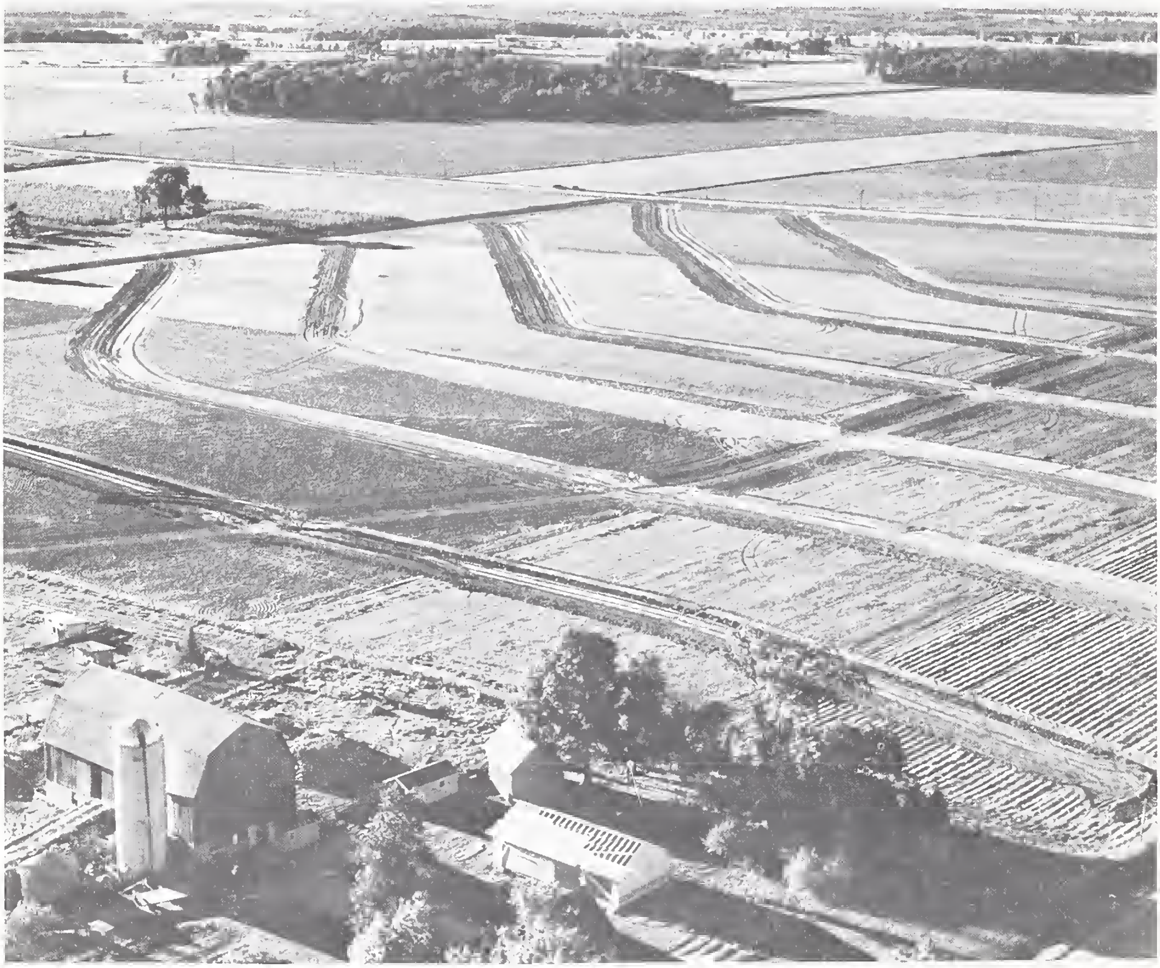


Figure 12-19.--Well-planned terrace system.

In some areas the feedlot slopes are long and subject to sheet erosion. Diversions or terraces can be used to reduce erosion but the ridge height and the base should be increased to about twice the usual size to allow for loss of capacity if the structures are trampled by stock.

11. DRAINAGE SYSTEMS

Water management by drainage measures can control surface or subsurface water. Adequate water management reduces wetness of the soil, lowers the water table, and provides a better soil condition for waste management systems.

SURFACE DRAINAGE

Surface drainage channels reduce both surface drainage and subsurface drainage problems. Figure 12-13 shows typical surface drainage channels.

Land grading can be beneficial on the waste management area or the disposal area. Grading is usually done on nearly level sites where runoff collects and remains in small depressions. Through grading the slopes are such that water does not pond but moves to waterways and other outlets, the runoff is uniformly spread over the site, and the soil does not become saturated.

The surface of lots can be completely reshaped by grading to provide better drainage with fewer outlets and thus make the runoff collection system less complicated.

SUBSURFACE DRAINAGE

Areas covered with waste, such as feedlots or holding areas, usually seal over so that subsurface drainage is not feasible. But seepage water or a high water table in soils around a site can be lowered by a subsurface drainage system along the perimeter of the area if the soils are suitable. This subsurface drainage provides better access to the lot and surrounding area. Poorly drained disposal sites in which the soils are suitable can also benefit by subsurface drainage.

Subsurface drainage can be provided by open ditches 5 to 6 ft deep, buried drains such as tile or corrugated plastic tubing, or other suitable conduits buried to a depth of 3 ft or more.

Relief Drainage

Relief drainage systems are used to lower a high water table that is generally flat or has a low gradient through open ditches or buried drains. The drains are usually spaced at intervals calculated by using one of several formulas.

Interception Drainage

Interception drainage systems are used to intercept, reduce the flow, or lower the flowline of water in the area. This can be done

through open ditches and buried drains. The design of these drains is based on study of ground-water hydraulics to determine the cause and possible solution of the problem.

Chapter 14 of the Engineering Field Manual and section 16 of the National Engineering Handbook provide guidance in design of subsurface drainage facilities.

12. SPECIAL DESIGN CONSIDERATIONS

Climatic factors that affect designs for capacity and stability must be considered during planning. Ice and snow can completely fill channels in some sections of the country. Drifting snow is especially damaging because during rains or warming periods channels may already be full of snow or ice and overflow. Culverts and other water control structures may freeze and not permit the facilities to function. The location of buildings, snow fences, barriers, and other facilities must be considered. Channels with flat side slopes, 4:1 or flatter, are blown clear of snow, melt sooner, or provide a sunken center for flow to start.

Channels, culverts, and other water control structures in areas subject to wind erosion may have similar problems with blown sediment, which must be removed manually. Measures for controlling wind erosion are mostly vegetative barriers at spacing designed to control the blowing.

Structures in holding areas for livestock are usually bare of vegetation and subject to trampling by stock and erosion by water. The structure should be designed with a larger channel, a higher ridge, and larger size to compensate for these conditions. The minimum size and capacity of structures in livestock areas should be about twice that of similar structures designed for less severe conditions. Wherever possible ridges for diversions or terraces in a feedlot or holding area should be so located that the top of the ridge is along the centerline of the stock fence.

Sedimentation and settling of solids is a problem in channels with a flat bottom or with a velocity less than 2.0 ft/sec. Channels carrying waste runoff and located outside a traffic area may be bare or vegetated. In some areas the vegetation in channels is lush, and annual weeds and grasses can clog the flow area. The vegetation can also cause rapid sedimentation of solids, thus reducing channel capacity. Added capacity and regular maintenance should be planned to solve these problems.

The variation in the properties of runoff carrying waste products should be considered when designing conservation practices.

Some possibilities to be considered follow:

1. Add capacity for sedimentation, including that from waste material.
2. Adjust channel grades to carry away waste material.
3. Design inlets, junctions, and channel curves to reduce the settling of solids.
4. Avoid rapid changes in grade and alinement.

5. Design inlets, culverts, and other structures so that flow is not restricted in those parts of the channel where sedimentation might occur.

Runoff that contains waste may be high in nutrient value, but it may also contain concentrations of salts that make it difficult to establish or grow vegetation in channels. Salts in runoff are especially detrimental to soil structure and drainage, resulting in poor drainage and wet soils. If vegetation is difficult or impossible to establish, the channel should be designed for stability under bare conditions.

Some facilities may serve as settling basins and holding areas for solid waste. Special designs and additional capacity must be provided for these structures.

13. APPURTENANT STRUCTURES

Culverts, spillways, chutes, and other structures are needed for controlling both water and waste. The design for these structures should meet the requirements for the entire waste management system.

Specially designed storage areas, channels, gutters, and curbs may be needed to handle the waste material on concrete paved lots.

Structures may be damaged by severe trampling of livestock, traffic by machinery and equipment, and corrosion by waste or gases. These possibilities should all be considered in both design and maintenance of structures.

PART VI - HOLDING PONDS

1. GENERAL

Holding ponds are the key components in many waste management systems. They are farm pond or reservoir type structures used to store polluted runoff or effluent from areas in which livestock are concentrated or other sources until the waste material has evaporated or can be disposed in an acceptable manner. Their primary function is temporary storage, not biological treatment of the waste as for disposal lagoons. Although their purpose is not trapping solid waste, significant amounts of solid waste do reach holding ponds because of site limitations and incomplete settling in debris basins and settling areas.

In waste management systems for open livestock feeding, holding ponds usually are located below debris basins, vegetated strips or waterways, low-gradient channels, etc., which are used to settle out solids in the runoff from the livestock area. In other waste management systems, liquid wastes are piped to holding ponds from facilities located either in buildings or open areas. In complete systems, holding ponds are the basins from which the liquid wastes are removed for reuse or final disposal or left to evaporate.

2. PLANNING

Holding ponds must be compatible with other components of the waste management system, and the performance or absence of each component should be carefully considered. The area available for installing waste management systems at existing livestock operations often is limited in size. The number and type of components and the site for a holding pond are thus restricted by lack of space. Such restrictions affect, sometimes adversely, the design, operation, and maintenance of holding ponds since they must perform the additional function of trapping solids as well as holding liquid wastes.

LOCATION

If space is adequate, the following items should be evaluated to determine the best location.

1. Proximity to the waste source, other system components, disposal area, dwellings, public roads, and streams or lakes

It is desirable to have the holding pond(s) near the waste source in order to keep the drainage area, a factor in sizing the pond, within acceptable limits. However, the distance should allow ample room for installing, operating, and maintaining the structures or vegetated areas needed to settle the solids from the runoff. Solids management can be accomplished much more satisfactorily in settling facilities than by allowing a large volume of solids to reach the holding ponds. If the holding ponds are to be dewatered through application on farmlands, they should be located as close to the disposal areas as practical.

Emergency spillway flows from holding ponds are potential pollution hazards to streams and lakes. The location should provide as much distance as possible between these facilities and surface waters.

Holding ponds can give off offensive odors. This possibility should be considered in selecting their location.

2. Soil and ground-water conditions

Seepage from holding ponds can contaminate ground water or nearby wells. This possibility must be considered in selecting sites for holding ponds. Although recent studies indicate that manure ponds seal with time under most soil conditions, holding ponds should be constructed in or of the most impermeable soils available in the vicinity of the waste source. State regulations for controlling seepage from lagoons and holding ponds and for locating such structures with respect to domestic wells must be complied with.

A detailed subsurface investigation usually is needed to determine the water-holding capacity of a site unless experience in the area has already shown that seepage is not a problem. Enough information should be obtained during the investigations to evaluate soil and bedrock characteristics and ground-water conditions, primarily to identify any soil horizon or rock stratum that may affect seepage and

to determine the depth to the water table. Field permeability tests may be required to indicate the relative permeability and water-holding potential of the various strata. The well permeameter method outlined in NEH, Section 8, Engineering Geology, and as Designation E-19 in the U.S. Bureau of Reclamation Earth Manual is the recommended field test procedure.

Laboratory permeability tests usually are needed when field investigations indicate that relatively impervious soil blankets are required to reduce seepage from holding ponds. These tests also may be needed to comply with some state regulations or to predict the permeability of earth embankments. The recommended procedures for testing blanket materials and treatments and for testing embankment materials are the constant-head permeability test with permeameter cylinder or the falling-head permeability test with permeameter cylinder. These tests are outlined in the Corps of Engineers Manual, EM 1110-2-1906, Appendix VII.

See part VIII of this chapter for additional guidance regarding seepage from holding ponds.

TYPES

The number and type of holding ponds needed in a particular system are influenced by such factors as:

1. Volume of liquid and solid wastes to be stored temporarily
2. Method and frequency of disposing of the waste materials
3. Soil and topography at the site

Holding ponds can be either embankment or excavated type since depth and shape are not so critical as for disposal lagoons and settling structures. But if the ponds are to receive large amounts of solids or to be dewatered by evaporation, depth becomes an important factor in planning the shape, type, and number of ponds for the particular site. Evaporation ponds must be shallow. If frequent clean-out of trapped solids is expected, two or more shallow holding ponds are preferable because they dry out faster and permit greater flexibility of operation and maintenance. Consideration of adequate maintenance during planning cannot be overemphasized. Experience with all types of ponds has shown that sediment takes a long time, even in arid areas, to dry out enough for removal with blade-and-scraper equipment. For maintenance with this equipment, holding ponds usually must be dewatered and all runoff bypassed. Thus, storage capacity is sacrificed for the time necessary to dry and scrape the pond. Wet solids can be removed with draglines, which limits the width of holding ponds to 50 ft.

3. DESIGN

Design criteria and procedures applicable to holding ponds are given in several references including:

1. National SCS engineering standards for ponds (Code 378) and holding ponds (Code 425).

2. State SCS standards and specifications for these practices.
3. Engineering Field Manual for Conservation Practices, chapters 1,2,3,4,6,11, and 17.
4. Federal, state, and local regulations or laws governing waste management, pollution abatement, health, etc.

Since state regulations vary considerably, state SCS criteria for holding ponds differ. Designs for holding ponds should be in accordance with state SCS standards, which must comply with state regulations and yet meet or exceed the minimum requirements of the national SCS standard. Because of the variation in standards and regulations, the criteria or procedures that follow are those that have wide application.

VOLUME

The volume of storage for holding ponds depends on:

1. Rainfall and runoff entering the pond and evaporation
2. Amount of solids (feces, urine, and sediment) delivered to the pond
3. Volume of other inflows such as washdown water or overflow from waterers, etc.
4. Time period between removal of liquid and solid materials

Excess rainfall entering holding ponds ranges from only that falling directly on the ponds as in places where all outside runoff is excluded from the ponds to large amounts of runoff from contributing drainage areas. To reduce the size of holding ponds, uncontaminated runoff should be diverted where possible. On the basis of research, storm rainfall-runoff curves have been established for open feedlots for cattle in some sections of the country. If applicable these rainfall-runoff curves can be used to determine the amount of runoff produced by the design storm specified in the state standard. Runoff from open livestock-feeding operations can also be estimated by the procedures given in chapter 2 of the Engineering Field Manual. A runoff curve number (CN) of 90 or 91 is recommended for unpaved lots and 94 or 95 for paved. Usually, antecedent moisture condition (AMC) II is used, but the AMC can be adjusted for the site in accordance with guidance provided in the field manual.

The quantity of manure entering a holding pond ranges from very little to the entire amount produced in the feeding operation. If the holding ponds are located below efficient settling basins or vegetated areas, only a small percentage of the manure is carried to the ponds, but in other systems all the manure is flushed into the ponds. If data on local manure production are not available, the figures for daily manure production in table 12-2 can be used in calculating the volume of manure entering holding ponds designed to retain all manure.

Research shows that the solids content of rainfall runoff from cattle feedlots is variable (see ch. 4, Waste Characteristics). Differences in rainfall runoff are caused by site factors such as slope, rainfall patterns, evaporation, and cattle stocking rates. In the

absence of local data from which to estimate the transportable solids content of runoff from cattle feedlots, the solids content for design purposes can be considered to be in the range of 0.75 to 1.0 percent, which is equivalent to 0.85 to 1.13 tons per acre-inch of runoff.

The percentage of solids entering the holding ponds depends on whether or not facilities, such as debris basins, low-gradient channels, vegetated areas, etc., are located above the ponds and on their effectiveness in settling the solids from the runoff.

Basic data for estimating the trap efficiency of these facilities are limited. Some studies have indicated that about 40 percent of the solids in runoff from feedlots settle out in a 30-min detention time, and two-thirds settle out if the runoff comes through a settling basin or is retained temporarily by broad-basin terraces. The percentage may be higher in debris basins that retain runoff for long periods and release it through pipes with slotted inlets or if the runoff travels through densely vegetated strips to the holding ponds. Therefore, the particular conditions must be evaluated in order to estimate the amount of solids that will enter the holding pond and the volume that the solids will occupy.

Data on the bulk density of settled solids in holding ponds are limited. The weight of the solid material varies, depending on the composition of the material and on the mixing with other sediment that occurs during travel to the pond. In the absence of accurate data for designing storage space for solids in holding ponds, the weight of dry solids per cubic foot of settled material can be considered to be in the range of 15 to 30 lb/ft^3.

In addition to runoff from rainfall and the solids entering the holding pond, other potential inflow must be estimated in determining volume requirements. Sources of additional water inflow can be washdown or sprinkling operations, watering facilities, etc.

Major factors that affect the volume necessary for holding ponds are the time intervals between dewaterings and solids removal. A holding pond should have enough capacity to store the runoff from normal rainfall and other waste water for the longest period expected between emptying plus the runoff to be expected from the design 24-hour storm. Volume should be provided for storing the solids accumulated during periods between solids removal. If holding ponds have no appreciable drainage area, volume should be provided for direct precipitation less evaporation plus the waste accumulated between emptyings.

If holding ponds are to be dewatered within a few days after runoff-producing rainfall, volume may be needed only for the runoff expected from the design 24-hour storm. The design 24-hour storm is set forth in the state SCS standard for holding ponds (Code 425).

The length of time between emptying and solids removal should be based on the plans for disposal of the waste. These plans must consider climate, crop growth and nutrient and water requirements, and the availability of equipment, labor, and land. For example, in some localities storage must be provided for inflow for several months to eliminate the necessity of dewatering the ponds during periods of freezing weather or excessive rainfall. In other localities it may be desirable to empty the ponds when crops can use the additional moisture. Special

frequency analyses of rainfall and runoff, reservoir operation studies, etc., may be required to determine the storage capacity of holding ponds. One such analysis may be applicable to a large area and thus simplify the procedure for designing the holding ponds.

EXAMPLE

To illustrate how these criteria are used in determining the volume of a holding pond for a 10-acre cattle feedlot at Lubbock, Tex., assume that:

1. Almost all uncontaminated runoff can be diverted and the amount of other potential inflow from waterers and the like is insignificant.
2. The site permits installation of only one holding pond and a low-gradient diversion to intercept and deliver runoff from feedlot to holding pond.
3. For some years it may be desirable to hold the liquid waste in the pond for 6 months (Sept., Oct., Nov., Dec., Jan., and Feb.) until crops can better utilize the water or to avoid dewatering during freezing weather.
4. Solid wastes will be removed from feedlot once or twice a year, but solids transported in runoff will enter the holding pond except for that settled in the diversion channel.
5. A 10-year period between removals of solids from pond is desired.

Problem:

Determine the volume of holding pond required to store runoff from normal rainfall from September through February, the runoff from a 25-year, 24-hour storm, and the 10-year accumulation of solids.

Solution:

1. From climatological records, such as those from the Weather Bureau summary for precipitation at Lubbock, determine the normal runoff during the 6-month period of September through February, which is the longest period expected between dewaterings. The normal or average runoff during each month can be estimated by applying the equivalent 30-day runoff curve number (table 12-8) to the mean monthly rainfall.

Table 12-8.--Runoff curve numbers (CN)

1-day runoff CN	30-day runoff CN
95	86
94	83
91	76
90	74
85	65
80	57
75	49

PRECIPITATION, LUBBOCK, TEXAS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
D	.38	.49	.94	1.62	2.15	2.59	2.18	2.00	2.67	2.70	.60	.72	19.04
F	19	19	19	20	20	20	20	20	20	20	20	20	-
1931	.32	1.98	1.34	1.82	1.32	.95	2.17	2.44	.72	3.47	1.39	1.44	19.35
1932	.93	1.09	.04	1.84	2.37	5.66	1.90	3.15	3.41	1.29	T	2.48	24.16
1933	.37	.95	.02	.06	2.97	.21	1.36	2.19	.71	.42	.99	.06	10.31
1934	.06	.06	1.98	1.08	1.26	.28	.65	1.66	1.86	.28	.55	T	9.72
1935	.15	.60	.89	.04	3.49	2.57	1.25	1.69	3.02	1.22	2.04	.33	17.29
1936	1.08	.02	.59	.92	5.86	.92	1.05	.13	13.93	1.52	.74	.21	26.97
1937	.26	.01	1.81	2.01	4.00	3.12	1.32	2.06	3.85	3.22	.07	.52	22.25
1938	.91	1.18	.49	.14	1.99	5.89	4.01	.47	.63	.51	.27	.03	16.52
1939	2.45	.19	.09	.28	1.82	.67	1.73	2.75	.01	.94	.18	.60	11.71
1940	.23	1.97	T	1.84	1.74	2.06	T	1.57	.73	1.07	2.35	.20	13.76
1941	.55	.61	3.56	2.23	12.69	4.13	3.68	1.85	4.47	5.89	.17	.72	40.55
1942	.04	.18	.51	3.25	.35	1.74	2.58	4.97	7.61	3.39	.01	2.80	27.43
1943	.04	.02	.25	.53	2.71	2.37	3.17	T	1.16	.10	.62	1.87	12.84
1944	1.28	1.36	1.09	.84	3.03	1.75	2.93	2.37	3.73	.80	1.72	1.64	22.54
1945	.69	.39	.10	.46	.46	.36	3.08	2.17	2.22	2.26	.27	.32	12.78
1946	1.18	.15	.76	.07	1.49	2.72	.58	3.55	3.59	4.67	.44	1.04	20.24
1947	.82	T	.92	1.13	6.03	.55	1.18	.10	.00	.74	.00	.51	11.98
1948	.11	1.59	.22	.48	1.91	1.36	1.22	.31	1.08	1.09	.02	.10	9.49
1949	3.85	.38	.78	1.78	6.95	4.62	2.47	2.36	4.53	1.02	.00	.39	29.13
1950	.23	.07	.00	.68	2.51	.77	2.67	1.40	2.24	.29	.03	.02	10.91
1951	.21	.72	.61	.55	2.61	1.91	1.92	3.93	.50	.64	.13	T	13.73
1952	1.16	.14	.02	3.39	1.73	1.76	3.31	1.17	.90	.00	.74	.22	14.54
G	.77	.63	.73	1.16	3.15	2.11	2.01	1.92	2.77	1.58	.58	.70	18.11
H	22	21	21	22	22	22	22	22	22	22	22	22	-

The estimated normal average runoff during each month at Lubbock is listed below.

Month	Mean rainfall	Runoff CN74
	Inches	Inches
January	0.77	0
February	.63	0
March	.73	0
April	1.16	0.05
May	3.15	1.01
June	2.11	.40
July	2.01	.35
August	1.92	.32
September	2.77	.77
October	1.58	.17
November	.58	0
December	.70	0
Annual	18.11	3.07

The estimated normal runoff during the 6-month period September through February is:

$$0.77 + 0.17 + 0 + 0 + 0 + 0 = \underline{\underline{0.94 \text{ inch}}}$$

2. Determine runoff to be expected from the 25-year, 24-hour storm. The 25-year, 24-hour rainfall (Exhibits 2-3 and 2-7, ch. 2, Engineering Field Manual) is 5.3 inches and the runoff, using CN 90, is 4.17 inches.

3. Determine volume required to store runoff in holding pond.

$$(0.94 \text{ in} + 4.17 \text{ in}) \times 10 \text{ acres} \times 3{,}630 \text{ ft}^3/\text{acre-in} = \underline{\underline{185{,}493 \text{ ft}^3}}$$

4. Determine volume required to store solids transported in runoff to holding pond. The average annual runoff was estimated (item 1) to be 3.07 inches. Use 3.1 inches. Assume that the solids content of the runoff is 0.75 percent, which is equivalent to 0.85 ton/acre-inch of runoff. Assume that 70 percent of the solids will enter the pond since only a low-gradient diversion is to be installed between pond and feedlot. Therefore, the solids delivery is:

$$(0.85 \text{ tons/acre-in}) (0.70) (3.1 \text{ in}) (10 \text{ acres}) = 18.4 \text{ tons per year}$$

Assume that the dry weight of the solids is about 30 lb/ft^3. The volume required to store the solids is:

$$\frac{(18.4 \text{ tons/yr}) (10 \text{ yr}) (2{,}000 \text{ lb/ton})}{30 \text{ lb/ft}^3} = \underline{\underline{12{,}266 \text{ ft}^3}}$$

5. The total volume of holding pond required to store the runoff and solids for the conditions of this example is:

$$185{,}493 + 12{,}266 = 197{,}759 \text{ ft}^3 \text{ or } 4.54 \text{ acre-feet}$$

Any freeboard will provide additional storage.

In areas where annual evaporation exceeds annual precipitation, it may be feasible to dewater holding ponds by evaporation. This dewatering method applies mostly to small feedlots or other livestock operations that have small amounts of runoff or effluent and to terrain where shallow ponds with a large surface area can be constructed.

SCS procedures used for making operation studies of water supply and large irrigation reservoirs can be used for designing evaporation ponds for waste management systems. However, the less complicated approach that follows is adequate for determining the surface area and depth of most evaporation ponds.

For a pond to dry by evaporation at least once a year, the annual inputs must not exceed annual evaporation. Inputs include:

1. Rainfall runoff from feedlot or similar area
2. Manure, both feces and urine
3. Waste water from overflow, washdown operations, etc.
4. Precipitation falling directly on pond

Outgo from pond is by evaporation only, if seepage is negligible.

To insure dewatering during a year of above-normal rainfall and below-normal evaporation, the annual rainfall used for design should be that expected 1 year in 25, and the annual evaporation used should be that expected 9 years in 10. The 4-percent-chance annual rainfall and the 90-percent-chance annual evaporation can be determined by using the procedures in Chapter 18 of NEH, Section 4, Hydrology, to analyze the annual rainfall and evaporation records applicable to the area. These annual data should extend over a period of at least 20 years and usually can be obtained from Weather Bureau records.

The 4-percent-chance annual rainfall and 90-percent-chance annual evaporation can be used to develop ratios that can be applied to mean monthly and annual data in estimating runoff and evaporation either for designing a single structure or as general design criteria for an entire area.

On the basis of climatic data for Lubbock and the feedlot conditions of the previous example, an analysis of the precipitation shows that the 25-year frequency annual rainfall is 33.67 inches, or $\frac{33.67}{18.11} = 1.86$ times the mean annual rainfall. Use of this factor and the 30-day runoff CN74 (from table 12-8) to determine the 25-year-frequency monthly and annual runoff is illustrated in the following discussion.

	Rainfall		Runoff	Evaporation	
Month	Mean	25-year frequency (mean X 1.86)	25-year frequency (using CN 74)	W.B. pan (mean)	90-percent chance shallow basin (mean X 0.70)
In	In	In	In	In	In
Jan.	0.77	1.43	0.13	3.50	2.45
Feb.	0.63	1.17	0.05	3.91	2.74
Mar.	0.73	1.36	0.10	6.89	4.82
Apr.	1.16	2.16	0.46	8.34	5.84
May	3.15	5.86	3.07	10.57	7.40
June	2.11	3.92	1.53	12.96	9.07
July	2.01	3.74	1.41	10.87	7.61
Aug.	1.92	3.57	1.29	9.41	6.59
Sept.	2.77	5.15	2.49	7.24	5.07
Oct.	1.58	2.93	0.87	6.04	4.23
Nov.	0.58	1.08	0.03	3.66	2.56
Dec.	0.70	1.30	0.09	3.06	2.14
Total	18.11	33.67	11.52	86.45	60.52

The evaporation rate from lake surfaces is lower than the evaporation rate from Weather Bureau pans. However, the evaporation rate from shallow ponds, such as an evaporation basin for waste management, probably is greater than that from larger lakes. Coefficients for converting Weather Bureau Class A pan evaporation to lake evaporation are given on figure 12-20. These coefficients may be increased slightly for designing evaporation ponds. The mean annual evaporation (Weather Bureau pan) in the example is 86.45 inches and the 90-percent-chance

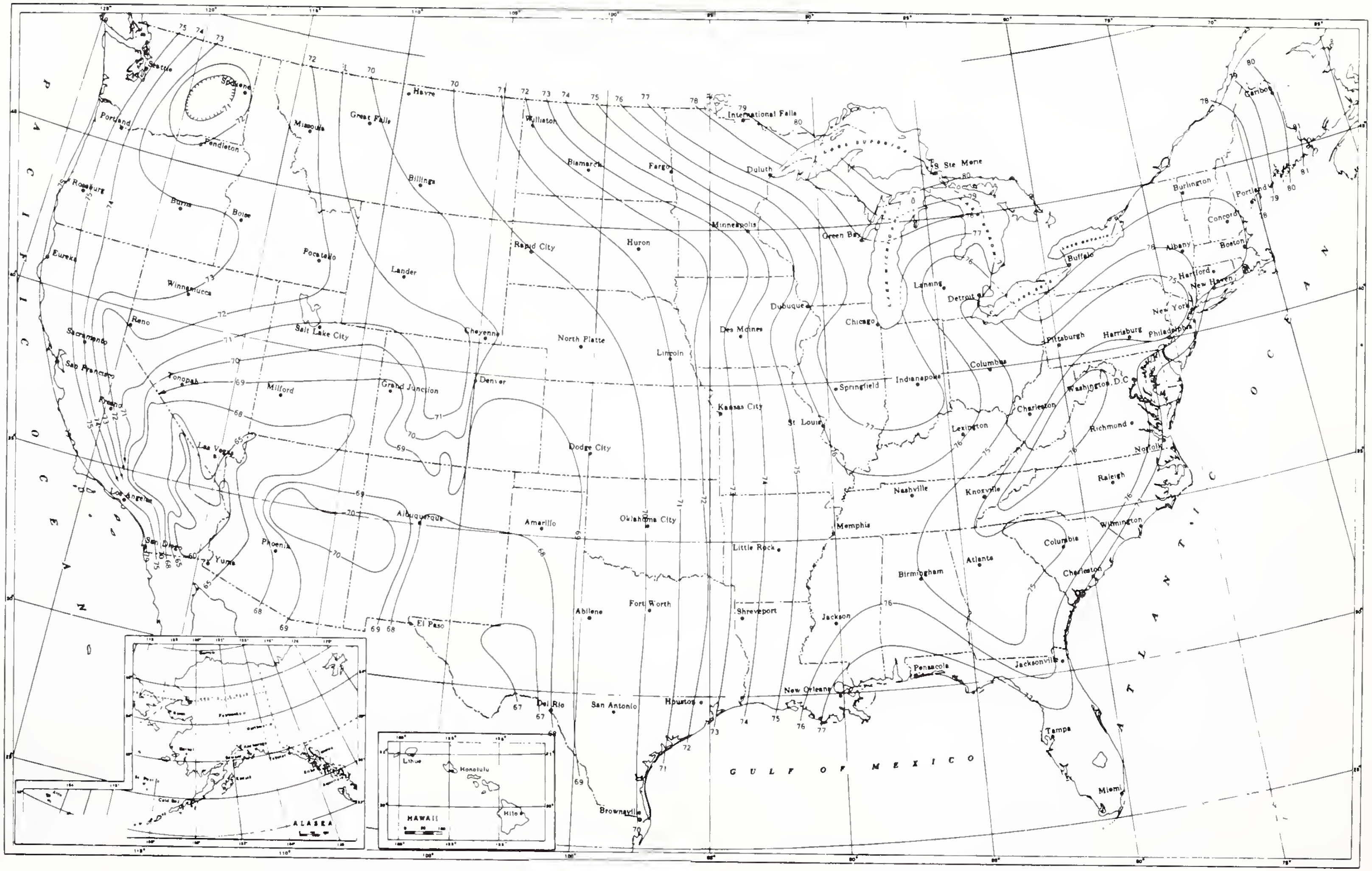


Figure 12-20.--Mean annual class A pan coefficient (in percent).

annual evaporation is 73.5 inches or 0.85 times the mean annual. The coefficient (fig. 12-20) for Lubbock is about 0.68. Therefore:

90-percent-chance W.B. pan evaporation = (0.85) mean.

90-percent-chance lake evaporation = (0.68) (0.85) or (0.58) mean.

90-percent-chance shallow basin evaporation is considered somewhere between these two figures or about 0.7 times the mean Weather Bureau pan evaporation.

The design of this evaporation pond assumes that all liquids entering the pond will be evaporated during the year. The equation for the surface area of the pond is derived as follows:

$$\text{(Pond area) (evaporation)} = \text{(pond area) (precipitation)} + \text{runoff} + \text{manure} + \text{waste water}$$

$$\text{Pond area (evaporation} - \text{precipitation)} = \text{runoff} + \text{manure} + \text{waste water}$$

$$\text{Pond area} = \frac{\text{runoff} + \text{manure} + \text{waste water}}{\text{evaporation} - \text{precipitation}}$$

where

Pond area is in square feet
Runoff, manure, and waste water are in cubic feet
Evaporation and precipitation are in feet

For the example feedlot it has been determined that:

1. The 25-year-frequency rainfall is 33.67 inches or 2.80 ft.
2. The 25-year-frequency runoff is 11.52 inches.
3. The 90-percent-chance shallow basin evaporation is 60.52 inches or 5.04 ft.
4. Volume required for 10-year accumulation of solids is 12,266 ft^3.
5. Waste water is insignificant.

$$\begin{aligned}\text{Feedlot runoff} &= \text{(10 acre) (11.52 in) (3,630 ft}^3\text{/acre-in)} \\ &= 418{,}176 \text{ ft}^3\end{aligned}$$

$$\begin{aligned}\text{Pond area} &= \frac{\text{Runoff} + \text{manure} + \text{waste water}}{\text{Evaporation} - \text{precipitation}} \\ &= \frac{418{,}176 + 12{,}266}{5.04 - 2.80} = \frac{430{,}442}{2.24} = \frac{430{,}442}{2.24} \\ &= \underline{192{,}162 \text{ ft}^2} \text{ or } \underline{4.41 \text{ acres}}.\end{aligned}$$

The maximum depth to which water will accumulate in the pond during the year can be estimated by making a simple reservoir operation study as illustrated, using the 25-year-frequency rainfall and runoff and the 90-percent-chance evaporation distribution previously listed.

The maximum water depth is in October and amounts to:

$$\frac{41.33 \text{ acre-in}}{\text{(12 in) (4.41 acre)}} = 0.78 \text{ ft}$$

(1) Month	(2) 25-year runoff X 10 acres	(3) 90-percent chance evaporation (shallow basin)	(4) 25-year rainfall	(5) Net evaporation (3)-(4)	(6) Net loss from pond (5) X 4.4 acre	(7) Volume remaining (2)-(6) + carryover from previous month
	Acre-in	In	In	In	Acre-in	Acre-in
Jan.	1.3	2.45	1.43	1.02	4.50	Dry
Feb.	0.5	2.74	1.17	1.57	6.92	Dry
Mar.	1.0	4.82	1.36	3.46	15.26	Dry
Apr.	4.6	5.84	2.16	3.68	16.23	Dry
May	30.7	7.40	5.86	1.54	6.79	23.91
June	15.3	9.07	3,92	5.15	22.71	16.50
July	14.1	7.61	3.74	3.87	17.07	13.53
Aug.	12.9	6.59	3.57	3.02	13.32	13.11
Sept.	24.9	5.07	5.15	-0.08	-0.35	38.36
Oct.	8.7	4.23	2.93	1.30	5.73	1/41.33
Nov.	0.3	2.56	1.08	1.48	6.53	35.10
Dec.	0.9	2.14	1.30	0.84	3.70	32.30
Jan.	1.3	2.45	1.43	1.02	4.50	29.10
Feb.	0.5	2.74	1.17	1.57	6.92	22.68
Mar.	1.0	4.82	1.36	3.46	15.26	8.42
Apr.	4.6	5.84	2.16	3.68	16.23	Dry

1/ Maximum water depth.

The depth required for solids storage (12,266 ft^3) is 0.11 ft. If the 25-year, 24-hour storm occurs when the water in the evaporation pond is at its maximum depth, the runoff from this storm will be 41.7 acre-inches (determined in previous example) and 5.3 inches more precipitation will fall on pond. This requires an additional depth of

$$\frac{41.7}{(12)\ (4.41)} + \frac{5.3}{12} = 1.23 \text{ ft}$$

Therefore, an evaporation pond 2 ft deep with a surface area of 4.41 acres meets the volume requirements for this site. The probability of the 25-year, 24-hour storm occurring when the water depth is maximum is not great. The need to include additional depth is based on evaluating the potential hazard of infrequent overflows at the particular sites.

If the surface area is less than 4.41 acres, the pond will not be dewatered (evaporated) annually as planned. Thus, if the surface area is reduced, another reservoir operations study must be made, using long-term climatic records in which a change in surface area with respect to depth is considered.

In this example the liquid wastes that can enter evaporation ponds were not considered. If additional inflows are expected, they must be considered in the operations study.

SIZING

Sizing of holding ponds to meet volume requirements can be done by using the same procedures used in designing other types of ponds and reservoirs. These procedures are discussed in chapter 11 of the Engineering Field Manual. Volume tables based on the prismoidal formula can be used to select the dimensions of holding ponds to be installed at relatively flat sites with most of the storage capacity below the natural ground surface. On sloping or uneven sites, enough topographic data are needed to develop elevation-storage relationships for sizing embankment-type holding ponds.

The limitations on depth and shape of holding ponds that are dewatered by pumping and that are cleaned out infrequently are imposed mostly by soil depth and topographic conditions. However, construction and maintenance equipment, such as draglines mentioned earlier, may restrict dimensions. In sizing evaporation ponds depth is a critical factor.

Embankment and excavation standards for holding ponds should equal or exceed those specified in the SCS standard for ponds (Code 378). Special consideration should also be given to:

1. Side slopes of excavations or embankments to accommodate any required sealing treatment and/or establishment and maintenance of vegetation.
2. Ramps for portable pumping equipment and blade or scraper machinery used during cleanout. If frequent solids removal is required, these ramps may need to be surfaced and to extend throughout one cross section of the pond. The ramps for portable pumps should be so located that they are readily accessible and that concentrated runoff cannot enter them.
3. Placement and spreading of spoil from excavated ponds so that the overflow is directed to the desired spreading area and that the spoil material is easily vegetated and maintained for protection against erosion and improved appearance.

INLETS

Inlets to holding ponds often require special treatment. Runoff entering excavated ponds can create a potential erosion hazard that results in increased sediment deposition or damage to treatment or lining for seepage control. Ramps, drop inlet structures, shaped and vegetated areas, or other measures may be needed to overcome this hazard and should be designed in accordance with appropriate standards. Pipe inlets, especially those that carry liquid waste from settling facilities to holding ponds, frequently are plugged by solids at slotted or perforated entrances. Completely trouble-free entrances for such installations are not yet developed. Designs for such inlets should therefore incorporate entrances that are less likely to clog but still filter the solids. Some solids must be allowed to pass if plugging is to be held within practical limits. Catwalks or other measures should be included to facilitate easy clearing of plugged inlets.

EMERGENCY SPILLWAYS

Emergency spillways should be designed to protect holding ponds from at least the 25-year, 24-hour storm. The discharge capacity of the principal spillways and detention storage should be considered in the design. Procedures for designing safe emergency spillways are given in the SCS Engineering Standard for Holding Ponds (Code 425) and in chapter 11 of the Engineering Field Manual.

Entrances to ungated outlets from holding ponds should be set no lower than the elevation required to store the design runoff and other inflows and the solids accumulation. Because inlet and outlet pipes and other appurtenances of holding ponds are in contact with wastes containing high concentrations of salts and other corrosive matter, they should be constructed of corrosion-resistant materials, such as high-sulfate-resistant concrete, asbestos cement, plastic, treated wood, etc. To date, polyvinyl chloride (PVC) pipe has been used extensively for appurtenances at holding ponds and similar waste facilities. It is cost competitive and easy to handle. But it should be the type that resists deterioration by sunlight and it should be installed in relatively low fills and exposed sections should be supported. The latter is important to insure proper pipe alinement and grade.

4. SAFETY

Other items to consider in planning and maintenance are screening, fencing, and posting warning signs around the holding pond and vegetating the embankment, spillway, and spoil. Layers of solids thick enough to support grasses and weeds can accumulate and float on ponds and are dangerous to persons or livestock that may venture onto and break through the layers. Guard fences and signs can help prevent such accidents. Although vegetation on the embankment, spillway, and spoil is primarily for protection against erosion, a well-maintained vegetal cover and screening also improve the appearance of holding ponds and make them more acceptable to the public.

5. CONSTRUCTION

Construction specifications and procedures for installing high-quality ponds and reservoirs for other purposes are also applicable to holding ponds.

6. OPERATION AND MAINTENANCE

Operation and maintenance of holding ponds are determining factors in the overall performance of the waste management system. Holding ponds must be dewatered as planned. Otherwise, their main purpose is defeated, and uncontrolled polluted runoff will continue. Solids must be removed as required to prevent encroachment on the storage capacity for runoff. Appurtenances such as pipe inlets and outlets must be kept in working order, and other maintenance normally associated with ponds must be provided.

PART VII - IRRIGATION SYSTEMS

1. GENERAL

Waste accumulated or retained in waste management system components, such as storage facilities, disposal lagoons, and holding ponds, is not suitable for free discharge into watercourses. At present, the most practical method of disposal of the trapped waste seems to be application or utilization on agricultural land. The most common means of transporting and spreading the liquid and slurry materials from the waste management system are manure wagons (ch. 15) and irrigation equipment.

The purpose of this section is to consider the major advantages and disadvantages of using irrigation equipment in waste management and the irrigation methods and systems that can be applied and adapted to waste disposal. The basic design criteria for various irrigation systems are not discussed since such criteria are available in other SCS national and state handbooks, guides, and the like. Some of the adjustments in design criteria needed if irrigation equipment and systems are used for waste disposal are discussed.

Spreading or applying liquid waste materials with irrigation equipment or procedures is not necessarily irrigation. The primary purpose is to dispose of the wastes in an acceptable manner. Usually it is not a question of meeting crop needs for increased production but a question of what is the maximum volume of waste, and at what rate it can be applied without excess runoff or damage to the crops or soils. The timing of applications is dictated mainly by the volume of waste accumulated and the climatic conditions.

True irrigation is seldom accomplished with liquid wastes from holding ponds and other waste-containing structures in agricultural waste management systems. The quantity of waste produced is not usually a dependable supply of water for irrigation, and the quality is unsuitable for sustained crop production. The water quantity and quality in effluents from sewage treatment or certain processing plants, however, may be sufficient to make crop irrigation practical. Again, however, the primary objective often is disposal of the effluent on as small an area as possible and not irrigation of crops.

2. ADVANTAGES AND DISADVANTAGES

Some advantages of disposing of liquid wastes by irrigation methods are:

1. Large amounts of effluents can be spread in a relatively short time. For example, 1 acre-ft of liquid waste (325,828 gal) can be spread in 24 hours with a 225-gal/min sprinkler but requires about 217 trips with a 1,500-gal manure wagon.
2. Waste effluents can be used to supplement irrigation water and to supply plant nutrients where regular irrigation of crops is practiced.

3. Irrigation methods may cost less than other disposal methods to install, may be cheaper to operate, and usually require less labor for equivalent volumes of application.
4. A high degree of automation is possible with some types of irrigation systems.
5. Effluents from holding ponds and similar facilities can be readily used in conventional irrigation systems. Manure guns can handle manure in slurry form directly from confinement and washdown operations.
6. Disposal can often be accomplished when wet conditions prohibit conventional hauling.

Disposal of wastes by irrigation methods has the following disadvantages:

1. The initial investment frequently is high although it may be no more than for other methods, depending on the particular circumstances.
2. An adequate disposal area may not be within economical pumping distance of the waste source.
3. Maintaining labor to operate some systems, especially hand-carry sprinkler systems, is a major problem.
4. Odor and drift from spray can be problems, depending on location and management.
5. Additional water supply and/or large storage basins may be required for dilution, flushing the equipment, and safe and efficient use of the effluent.
6. Runoff is a potential pollution hazard.

3. SUITABILITY AND LIMITATIONS

Sprinkler and surface methods are most commonly used to apply waste water to land. The kinds of systems are designated according to the type of equipment or surface configuration used to apply water. For example, the following sprinkler systems are used:

1. Hand-move or hand-carry
2. Big gun, both hand-move and traveling
3. Towline
4. Side-roll
5. Rotating-boom
6. Self-propelled center-pivot
7. Manure gun
8. Solid set

Surface irrigation methods include the following systems:

1. Level and graded borders
2. Level, graded, and contour furrows.

3. Contour levees and contour ditches
4. Corrugations
5. Wild and controlled flooding

Both sprinkler and surface irrigation are being used to some extent to dispose of liquid waste. Both methods have distinct adaptations and limitations for both true irrigation and waste disposal. Most of these irrigation methods and systems are discussed in various chapters of Section 15, Irrigation, of the National Engineering Handbook. Their suitability and limitations for waste disposal are discussed in the following pages.

In general sprinkler systems permit waste disposal on rolling and irregular topography, which could not be done economically with surface systems. Another advantage is that some sprinkler systems can be automated. Automation increases initial and operating costs, but it reduces labor requirements. More uniform applications of waste material probably are obtained with sprinklers than with surface systems except the level or basin systems or a well-designed and well-managed graded border system.

The type and size of sprinkler systems suitable for waste disposal as well as the feasibility of using irrigation methods for this purpose depend on factors such as:

1. The amount of waste to be handled
2. Solids content of the effluent
3. Soils, crops, and proximity of disposal area, which affect the permissable application rates and volume and the pipe size, power, etc. required to handle waste

Usually the more liquid wastes there are to handle, the more practical disposal with irrigation equipment and methods becomes.

Whether the various types of irrigation equipment can handle waste water depends on its solids content. The percentage of solids in waste water depends to a great degree on the kind of collecting, settling, and storage facilities used in the particular operation. Liquid waste with a low solids content, such as that in holding ponds that trap only runoff or other water that has already passed through a settling area or the effluent from disposal lagoons and municipal treatment plants, can be handled by almost any irrigation equipment including that used in surface methods. Such waste water may have a solids content of less than 1 or 2 percent and can be discharged through sprinkler nozzles as small as 3/16 inch if hay, straw, hair, wood chips, and the like have been screened out.

Equipment such as agitation devices and pumps with chopper blades usually is required if the solids content exceeds 4 or 5 percent. Solid and liquid manure collected in concrete storage facilities and in pits under slotted floors is an example. This material can be pumped through pipelines and sprinklers, but big-gun or manure-gun nozzles are required for field application. The nozzles of such guns range from 5/8 inch to 2 inches in diameter.

Sprinklers 1/2 inch in diameter or larger are usually required for waste with 1 to 4 percent solids content. Some researchers and

experienced operators advocate diluting wastes so that the solids content is between 1 and 4 percent even though pumps and sprinkler guns can handle thicker material. Such dilution reduces agitation problems and the possibility of plugging.

The soils in a disposal area and the proximity of the area to watercourses, roads, populated areas, and the like are major factors in determining whether a particular type of sprinkler system or surface irrigation system is suitable for waste disposal. For example, the runoff potential is high if some irrigation methods are used on sloping soils that have a slow intake rate. Odor and spray drift are greater and more offensive for some application systems than for others.

Tables 12-9 and 12-10 summarize characteristics of irrigation systems useful in determining their suitability for waste disposal.

SPRINKLER METHODS

The plus and minus features of some individual sprinkler systems for waste disposal follow.

Hand-Move or Hand-Carry Sprinkler Systems

These systems can be designed to function efficiently on almost any site suitable for sprinkler irrigation. They can be used on both small and large areas. The major problem in using such systems for waste disposal is obtaining the labor to move and operate them.

Big-Gun Sprinkler Systems

These systems can handle manure slurries if they are properly equipped with solids-handling pumps and agitation equipment. They require a high operating pressure, ranging from 50 to 130 psi, and are capable of discharging 100 to 1,200 gal/min with a diameter of coverage ranging from about 120 to 620 ft. Some large guns have an average discharge rate of more than 0.5 inch per hour; if they are not moved properly, runoff and uneven distribution of manure are hazards. Spray drift can also be a problem. The principal advantage of a big-gun sprinkler system is that it can be automated. Traveling guns are self-propelled by water turbines or cylinders or winch-propelled by auxiliary engines. These units drag as much as 660 ft of flexible hose behind them allowing application of effluent to strips as long as 1/4 mile. Their speed can be varied from 0.4 to 10 ft/min, which permits light or heavy applications. They can be used on irregularly shaped areas and rough terrain.

Manure-Gun Systems

Manure guns have characteristics similar to those of the big-gun sprinklers described. The main difference is that the sprinkler nozzles are designed specifically for handling liquid manure. Some have rubber

Table 12-9.--Comparison of some irrigation systems

Irrigation system	Relative investment cost[1]	Relative labor required[2]	Crop and soil limitations	Optimum size
		Percent		Acres
Small to medium sprinklers, hand-move.	1.0	100	Inconvenient for tall crops	1 to 80.
Big-gun sprinklers and lateral, hand-move with wagon.	1.2	75	Best for permeable soils; requires alleyway for row crops.	40 or more.
Tractor-tow lateral	1.5	40	Requires wide center strip if row crops; requires alleyway for row crops.	20 or more.
Traveling sprinkler unit, self-propelled or winch-propelled.	1.7	30	Requires alleyway; good for tall crops and orchards.	1 to 80 or more per unit.
Rotating-boom, winch-propelled.	1.8	30	Requires alleyway; good for tall crops; requires fairly level terrain.	20 to 80 or more per unit.
Center-pivot circular self-propelled.	1.8	15	Excellent for tall crops; maximum slope 5-10 percent; requires square fields with no obstructions.	160 best but down to 40.
Side-roll, power wheel-move lateral.	1.9	40	Low-growing crops	20 to 40.
Sequencing solid set	4.0 and up	20	Generally limited to high-value crops.	1 or more.
Solid set	5.0 and up	20	Limited to high-value crops	1 or more.

1/ Relative initial investment cost per acre for complete system including well, pump, power unit, and sprinkler system for an optimum acreage for each method compared with that for a hand-move system.

2/ Relative overall labor required per acre per season to set up and operate the irrigation system compared with that for a hand-move system.

Table 12-10.--Waste disposal system selection chart*

Factor Considered	TYPE OF SYSTEM: Tank Wagon	Sprinkler								Gravity	
	Honey Wagon	Hand-Carry Sprinkler	Traveling Gun	Towline	Manure Gun	Solid Set	Side Roll	Boom	Center Pivot	Gated Pipe	Open Ditch
Soil Type	Suitable for use on soils with a wide range of intake rates								Moderate to high intake soils	Soils with moderate to low intake rates	
Surface Topography	Adaptable to a wide range of surface topography						Limited to moderately undulating topography			Limited to moderate to flat slopes	
Labor Required	Very High on large operations	High	Low	Moderately low	High on large operations	Very low	Moderate		Very low	High	Very high
Management required 1)	Low	Moderately Low		Moderately low						High	Very high
Flexibility for Expansion	Inflexible 3)	Moderate	Inflexible 3)	Moderate		Inflexible 3)		Inflexible 3)	Inflexible 3)	Very flexible	
Initial Investment	Low to Moderate		Moderate	Low to Moderate		Highest	Low to Moderate		High	Low to Moderate	Lowest
Operating Costs 2)	Moderate to High		High	Moderate to High						Low	
Crop Suitability	All except tall growing crops	All	All with Adaptations				All except tall growing crops	All		All	
Size of Operation	Small to Medium Size		All Sizes		Small to medium size	All Sizes			Large	All sizes; depends on topography	
Type of Effluent	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only			Well filtered liquids	Liquids only	

Note: 1) Management refers to the skill required, or the ability to set the system and go off and leave it.

2) Operating costs are a small factor in selecting a waste disposal system.

3) Of course another system may be purchased.

*From THE MISSOURI APPROACH TO ANIMAL WASTE MANAGEMENT, Bulletin MP232/71/IM

orifices designed to reduce clogging problems. The nozzles operate in a pressure range of 20 to 100 psi and discharge from 35 to 160 gal/min with a diameter of coverage ranging from 90 to 200 ft. Most manure guns are mounted on individual stands that must be moved by hand or dragged in some manner.

Towline Sprinkler Systems

These systems, sometimes called end-tow or tractor-tow laterals, can be used for waste disposal in much the same way as hand-move systems. They require less labor than hand-move systems since they can be dragged from one setting to another. Tow laterals are used in conjunction with underground pipelines or portable mainlines located in the center of the disposal area. Portable mainlines are sometimes laid in a shallow V-ditch to allow the laterals to be pulled across them. A wide strip in the center of the field is required for moving the laterals without damage to row crops.

Side-Roll, Rotating-Boom, and Solid-Set Systems

These systems, like hand-move and towline systems, can be sized to handle waste that has a low solids content. The side-roll and rotating-boom sprinklers can be power moved, thus reducing labor requirements. Because of their high initial cost, they are usually limited to operations regularly utilizing large amounts of effluent or where waste is mixed with irrigation water.

Center-Pivot Sprinkler Systems

These systems also have a high initial cost that limits their use for waste disposal. They can handle effluent that has a low solids content. These systems operate on a high pressure (usually greater than 65 psi) at the pivot and have a high application rate at the outer one-fourth of the lateral. They are best suited to use on soils that have a moderate to high intake rate.

SURFACE METHODS

Pollution from runoff or tailwater is a major concern in considering surface irrigation for disposal of waste water. Other important considerations are what distribution facilities are practical for handling contaminated water and what effect will such water have on the performance of the surface systems.

Liquid wastes containing less than 4 to 5 percent solids can be handled by most of the conventional distribution facilities used in surface irrigation, such as underground irrigation pipelines, portable pipelines, and earth or lined irrigation field ditches. The waste water can be discharged from field ditches to individual furrow, borders, etc. through turnouts, spile tubes, and siphon tubes. The water from pipelines can be applied through gated pipe.

The amount and type of labor available and the ease of cleaning and maintenance must be considered in selecting distribution facilities for waste management systems. Labor, maintenance, and limited odor make pipelines or permanent ditches with large turnout structures seem to be the best distribution system for surface application methods. Portable pipelines and gated pipe give flexibility, especially to small waste management systems.

Solids in waste water tend to settle out near the point of discharge, filling furrows or forming deposits in borders near the ditch or pipeline. For these reasons slurries cannot be spread successfully by surface irrigation methods.

Level-Furrow, Level-Border, and Contour-Levee Systems

These systems permit positive control over water applications and rainfall runoff. The pollution hazard from tailwater is less than for most of the other surface methods. The level and basin methods can be used effectively to dispose of waste water that has a low percentage of solids if the soils in the disposal area are suitable for surface methods. The level methods for waste disposal are best suited to slopes of less than 1 percent. Land leveling usually is required to install them.

Graded-Border, Corrugation, and Contour-Ditch Systems

In these systems some runoff or tailwater is inevitable regardless of the techniques used. Tailwater recovery systems or other measures should be installed to prevent pollution from runoff. For waste management these systems have the disadvantage of high labor requirements. Irrigation streams must be properly manipulated for uniform applications, and land leveling usually is necessary.

Wild-Flooding Systems

In these systems usually there are no surface land configurations or structures other than pipe or ditch distribution measures for controlling water applications. Such systems should not be used for disposal of waste water unless the disposal area is large enough or so located that waste-water runoff is not a pollution hazard to watercourses, adjoining lands, or rights-of-way.

Controlled-Flooding Systems

Certain types of these systems have been used successfully to dispose of liquid wastes. One such system consists of only a pump and portable aluminum pipe to deliver water from a holding pond to a disposal area that has level, closed-end terraces. The water is discharged at one point on the channel or upslope side of each terrace. Although water distribution is poor, protection against tailwater is good. Again, the suitability of controlled-flooding systems for waste disposal depends mainly on the measures used to control tailwater and on the size and location of the disposal area.

4. DESIGN CONSIDERATIONS

Design criteria for sprinkler and surface irrigation systems and their components are listed in various national and state handbooks, practice standards, irrigation guides, etc. Sprinkler, pump, and other performance data and design criteria provided by manufacturers supplement SCS criteria. The applicable criteria should be followed in designing systems for disposing of liquid wastes. The following factors should also be considered.

PUMPS AND NOZZLES

Pumping equipment and sprinkler nozzles must be capable of handling the effluent produced at a particular site. Because consistency or solids content of effluent varies, pumps and sprinkler nozzles should be selected after a thorough evaluation of the effluent and on the basis of manufacturers' recommendations on the capability of equipment (ch. 15) to handle the particular waste material.

PIPELINES

Pipelines used in waste management systems can be of the same type and general design used in normal irrigation systems. Because of the corrosiveness of the effluent, underground pipelines should be constructed of plastic or asbestos-cement pipe and portable aluminum pipelines should be clad both inside and outside. If possible, clear water should be used for flushing pipelines and other waste-disposal equipment.

If the waste water contains an appreciable amount of settleable solids, the recommended pipeline velocities are 2.5 to 8.0 ft/sec to minimize sedimentation and friction losses. Friction losses in the pipelines can be assumed to be the same as the losses for clear water. But, a 10 percent increase in horsepower is recommended for pumping to offset the higher viscosity of the liquid.

Underground pipelines are recommended if large amounts of effluent must be disposed on a year-round basis. If plugging of pipelines is expected to be a major problem, consideration should be given to using portable pipe laid on the surface of the ground, especially if thick slurries must be handled without prefilling and flushing the pipeline with clear water.

APPLICATION RATES

The application rate should fit the intake rate of the soils in the disposal area. If the application rate is excessive, there is danger of polluting surface waters or adjoining areas by runoff. The design application rate should be conservative and usually lower than the maximum allowable rate given in the appropriate irrigation guide since in time the soil intake rate may be reduced because of the solids and high salt content in some waste waters.

CAPACITY

The capacity of irrigation systems for disposal of liquid wastes is based on several factors, but of major importance are volume of wastes to be disposed, days and operating hours per day allotted for disposal, maximum application depth, size of disposal area, and the like. A point of emphasis is that some state regulations specify the capacity of disposal systems in terms of the minimum number of days allowed for emptying holding facilities, and design must comply with these regulations. The maximum application depth may be limited by the amount of nutrients that can be added to the soil and its plant cover each year rather than by the moisture-holding capacity of the soil. This is different from normal irrigation design. Another important consideration is that the waste-water storage capacity has a significant bearing on system capacity and size of disposal areas. Reservoir operation-type studies may be required for large waste management systems to size the disposal area in relation to storage in order for waste-water applications to be made at times when crops can utilize the moisture or nutrients.

5. OPERATION AND MAINTENANCE

Experience to date indicates that proper operation and maintenance are as critical to irrigation systems for liquid-waste disposal as they are to regular irrigation systems. A difference, however, is that disposal of waste material becomes an unpleasant chore that results in little profit to the owner. There may be some benefits from using the nutrients and moisture in the waste material for crop production. But these benefits usually can be gained as cheaply and more pleasantly by other means. The nature of the work intensifies the problem of getting and keeping labor, sometimes called "dung flungers," to operate and maintain the systems.

The nature of waste disposal contributes to the tendency on the part of many operators to wait until holding facilities are full or overflowing before emptying them or to leave hand-move sprinklers too long in place. Such deficiencies increase the potential of pollution from runoff and deep percolation. Abandonment of some manure-handling sprinkler systems has resulted from the operator's reluctance to operate and maintain the systems on the frequent cycles planned. These problems must be considered during planning and must be coped with by management. The most economical system for most operations probably is one that is more costly initially but one that is automatic, simple to operate, and as practical and maintenance-free as possible.

Other recommendations for operating and maintaining irrigation systems used for waste management are:

1. Keep debris out of waste water.
2. Follow the equipment manufacturer's recommended maintenance program.
3. If screened intakes are used to reduce plugging of pumps or nozzles, clean the screens regularly.

4. If possible, flush pumps and other irrigation equipment with clear water after each use to help prolong their life. Flushing not only cleans up the equipment but also washes solids from foliage.
5. Fill underground pipelines with clear water before using them to deliver slurry materials to help eliminate dead spots of solids.
6. Clear sprinkler nozzles and remove solids buildup frequently and routinely.

PART VIII - POND SEALING OR LINING

1. GENERAL

Most states prohibit discharge of animal wastes to surface or ground waters. Some states have strict limitations on allowable seepage from waste-holding ponds or lagoons, often requiring their sealing or lining. Conventional methods for pond sealing or lining are:

1. Compacting inplace or imported soils.
2. Sealing with Bentonite
3. Treating with chemical additives
4. Sealing with flexible membranes, i.e., plastic, rubber, or asphalt-sealed fabric
5. Installing rigid linings, i.e., concrete, soil-cement, or asphalt

Recent research has investigated the sealing characteristics attributed to animal manures. Preliminary reports indicate that a fine sand (Delhi, SM) has been sealed within 2 months of filling with dairy wastes.

2. METHODS

COMPACTION

Sealing by compaction alone is limited to sites that have a wide range of particle sizes, from small gravel or coarse sand to fine sand with enough clay and silt, usually 10 percent or more, to effect a seal.

Sealing by compaction is relatively simple. Prepare the site for sealing by removing all brush, roots, sod, and large rocks. Scarify the soil to a depth of 8 to 10 inches with a disk, roto-tiller, pulverizer, or similar equipment. With moisture conditions at optimum, roll the loosened soil to a dense, tight layer with four to six passes of a sheepsfoot roller.

If the impounded water is less than 10 ft deep, the compacted seal should be at least 8 inches thick. If the water is more than 10 ft deep, thickness of the seal should be increased proportionately since seepage varies directly with the depth of impounded water. Seals thicker than 8 inches must be compacted in two or more layers, each

no more than 8 inches thick. Thus, if the water is more than 10 ft deep, the top layer or layers must be removed and stockpiled while the bottom layer is being compacted.

Sites with too little clay to prevent excessive seepage can be sealed with an earth blanket of suitable material hauled to the site. The particle sizes of the blanket material should range from small gravel or coarse sand to fine sand, silt, and clay. The clay particles should make up about 20 percent of the weight. Adequacy of the material for sealing and the thickness required should be based on results of laboratory tests and a seepage analysis or on local experience.

After the site is prepared for sealing, spread the earth material uniformly in layers 6 to 8 inches thick. With moisture conditions at optimum, compact each layer thoroughly by four to six passes of a sheepsfoot roller before placing the next layer.

In many places a cover of gravel 12 to 18 inches thick is placed over the blanket for protection against the cracking that results from drying and against the rupturing that results from freezing and thawing.

BENTONITE

Bentonite is suitable for use on soils that have a high proportion of coarse-grained particles and insufficient clay for sealing. It is a natural clay material that has been processed and consists of a hydrous silicate of sodium composed chiefly of montmorillonite. A representative chemical analysis of dry Bentonite follows.

Material	Percent
Silica	56 to 66
Alumina	18 to 24
Ferric oxide	2.5 to 5
Ferrous oxide	0.3 to 0.7
Lime	0.4 to 1.0
Magnesia	2 to 2.5
Soda	1.8 to 3
Potash	0.2 to 1
Sulphur	0.1 to 0.5

Bentonite absorbs several times its own weight of water and at complete saturation swells as much as 8 to 20 times its original volume. If mixed in correct proportions with well-graded coarse-grained material, thoroughly compacted, and then saturated, the particles of Bentonite fill the pores so that the material is nearly impervious to water. But on drying Bentonite returns to its original volume, leaving cracks. It is not usually satisfactory for sealing ponds in which the water level fluctuates greatly.

The rate of application ranges from 1 to 3 lb/ft^2, depending on the site material and the depth of water to be impounded. An engineering analysis of the materials and site conditions based on field investigations and laboratory tests to determine the rate of application is essential.

Bentonite should be spread uniformly over the area to be treated at the rate determined by the laboratory analysis. It is then thoroughly mixed with the soil to a depth of at least 6 inches. A roto-tiller is best for this operation, but a disk or similar equipment can be used. The treated area should then be compacted with four to six passes of a sheepsfoot roller.

The moisture level of the soil material to be treated should be optimum for good compaction after Bentonite is applied. If the soil is too wet, sealing should be postponed. If it is too dry, water should be added by sprinkling.

Since the pond may not be filled for some time, a mulch of straw or hay pinned to the surface by the final passes of the sheepsfoot roller may be needed to protect the material against drying and cracking.

CHEMICAL ADDITIVES

Excessive seepage often occurs even in fine-grained clay soils because the clay particles are so arranged that they form an open, porous, or honeycomb structure. Applying small amounts of certain chemicals, called dispersing agents, to these porous aggregates disperses them and reduces permeability. Chemical treatment is not effective in reducing seepage from ponds that are alternately wet and dry.

For chemical treatment to be effective, more than 50 percent of the soil in the area to be treated should consist of fine-grained material (silt and clay finer than 0.074 mm diameter) and at least 15 percent of clay finer than 0.002 mm diameter. The content of soluble salts should be less than 0.5 percent (based on dry weight). Chemical treatment is not effective in coarse-grained soils.

Many soluble salts meet the requirements of a dispersing agent, but sodium polyphosphates and sodium chloride (common salt) are most commonly used. Of the sodium polyphosphates, tetrasodium pyrophosphate (TSPP) and sodium tripolyphosphate (STPP) are most effective. A seepage analysis based on a thorough field investigation and laboratory tests is essential to determine which dispersing agent is most effective and the rate at which it should be applied.

The dispersing agent is first mixed with the surface soil and than compacted to form a blanket. For depths of water up to 8 ft, the blanket should be at least 6 inches thick. For greater depths it should be 12 inches thick, treated in two 6-inch lifts. A minimum thickness of 12 inches is needed for all areas in which the water level fluctuates greatly.

As a part of site preparation, rock outcrops, crevices, and other exposed areas of highly permeable material should be covered with 2 to 3 ft of fine-grained material. This material should then be thoroughly compacted. In areas of cavernous limestone the success or failure of the seal may depend on the thickness and compaction of this underlying blanket.

Operating the mixing equipment in two directions produces the best results. Each chemically treated layer is then thoroughly compacted by four to six passes of a sheepsfoot roller.

For good compaction the moisture level in the soil should be near optimum to a depth of 12 inches. If the soil is too wet, treatment should be postponed. Polyphosphates release water from the soil, and the material could easily become too wet to handle. If the soil is too dry, water should be added by sprinkling.

The seal should be protected against puncture from livestock trampling. The area near the normal waterline should also be protected against erosion by a 12- to 18-inch blanket of gravel or other suitable material.

Cationic emulsions are also accepted sealants. The sealant is waterborne and therefore is placed in the reservoir water. The application rate must be determined by field or laboratory evaluation of the soils to be sealed.

FLEXIBLE MEMBRANES

Polyethylene and vinyl membranes for pond linings should be at least 8 mils thick for all material no coarser than sands, either clean or silty, and 12 mils thick for all gravels, clean, silty, or clayey. Butyl-rubber covers should be at least 20 mils thick for sands and 30 mils thick for all gravels.

All membranes should be of a quality that meets or exceeds the minimum requirements set forth in SCS standards and specifications.

If the material over which the lining is to be placed is stony or of very coarse texture, it should be covered with a cushion layer of fine-textured material. Banks, side slopes, and fills should be uniformly sloped no steeper than 1 to 1 for exposed lining and 2-1/2 to 1 for covered lining. The protecting cover tends to slide on the lining if placed on steeper slopes.

Nutgrass, Johnsongrass, quackgrass, saltgrass, and certain other plants penetrate both vinyl and polyethylene film. If these grasses are present, it is best to sterilize the subgrade, especially the side slopes. Several good chemicals that can be used are available commercially.

Linings are usually laid in sections or strips with a 6-inch overlap allowed for seaming. Vinyl and butyl-rubber linings should be laid smooth but slack. Polyethylene should have up to 10-percent slack. Care in handling is needed at all times to avoid puncture. The top edges must be anchored. The top 8 to 12 inches of the lining should be buried in a trench and secured with compacted backfill.

Because of their weakness, polyethylene and vinyl membranes should be protected against mechanical damage with a cover of earth or of earth and gravel at least 6 inches thick.

Butyl-rubber membranes need not be covered unless the area is traveled by livestock or likely to be punctured by swimmers or fishermen.

RIGID LININGS

Reinforced concrete, pneumatically applied concrete, and soil cement are common materials for lining leaky ponds and reservoirs.

Instructions for use of these materials is available from the Portland Cement Association and cement companies.

Asphaltic pavements are also common seals for leaky ponds and reservoirs. Information on these is available from the American Asphalt Institute and petroleum companies.

The quality of materials used as sealants should meet applicable SCS standards, SCS Code 521, and Section 2 of the National Engineering Handbook.

The effectiveness of chemical sealants and cationic emulsions in contact with animal wastes has not been determined. Numerous Bentonite installations have proved satisfactory to date.

SEALING WITH MANURE

Manure from dairy cows in a confined operation effectively sealed a holding pond constructed in soils of predominantly fine sand. Sealing occurred within 60 days of initial filling. The researchers postulate that coarser soils will also seal from organic loadings of animal wastes. The mechanism of sealing is attributed to the physical retention of organic matter in the soil pore space followed by the growth of micro-organisms or slimes.

The time required to reduce seepage to an acceptable level depends on soil type, head of water, and organic loading rate. The potential for ground-water pollution during the sealing time may be significant where depth to ground water is shallow. Since sealing occurs from the bottom up, an increase in storage depth may allow "overflow" of the seal. Depth of the water table and frequency and duration of storage have an effect on the pollution potential. In addition it has been found that reestablishment of a seal is necessary in ponds that are alternately wet and dry. The time required for resealing is equal to that required for the initial sealing.

There is much less detailed information on the sealing characteristics of chicken and swine wastes, but it is believed that the two-stage mechanism of sealing is the same for any animal waste material.

Available data on the sealing characteristics of manure are related to anaerobic installations. Researchers indicate that the wetted bottom and sides of both aerobic and anaerobic lagoons are under essentially anaerobic conditions and that the sealing characteristics do not differ.

Research and practical experience in manure sealing of lagoons and waste storage facilities are not refined to the point that positive recommendations can be made. Until such time as more definitive information is available, reliance on such sealing techniques may be subject to questions. Owners and operators as well as local and state regulatory agencies should be aware of the risks involved and should concur in their use before such sealing measures are recommended.

3. CONCLUSIONS

In the absence of additional local data the following conclusions can be drawn concerning the sealing of waste storage facilities:

1. Barriers to the seepage of stored animal wastes to ground water in order of decreasing effectiveness for any one soil are:
   a. Structural tank cast in place or preformed
   b. Flexible membrane, plastic or rubber
   c. Soil cement
   d. Asphaltic lining
   e. Bentonite, chemical additives, cationic emulsions, or manure
   f. Compaction
2. The sealing or lining used should meet the requirements of water quality regulations
3. With owner and regulatory agency concurrence manure can be considered an adequate sealant in soils of sandy loam or finer texture.
4. Sealants subject to cracking or drying should be restricted to areas where the ground-water level is 20 ft or more below the bottom of the pond.

CHAPTER 13. SOLID WASTE MANAGEMENT

Compiled by John P. Burt, sanitary engineer, SCS, Jackson, Miss.

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CHAPTER 13. SOLID WASTE MANAGEMENT

1. GENERAL

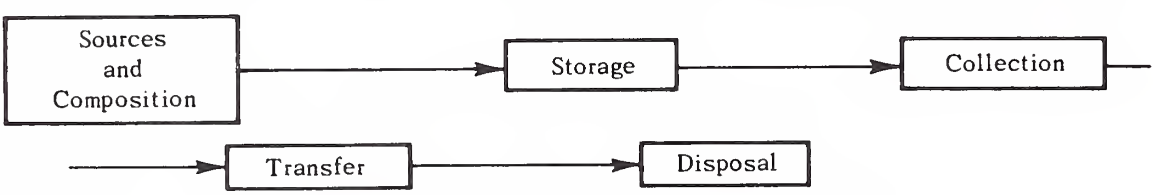
America's abundant natural resources have influenced our attitude toward consumption and disposal from the time of discovery until today. For example, since little value was placed on timber, the early settlers often cut and burned the trees to clear the land for other uses.

Today, individuals consume soda pop and discard the bottles without considering the value of the glass in the bottles since the glass companies can usually buy materials for new glass for less than it costs to recover the old bottles. The abundant supply of raw material for various items has supported the attitude of discarding any item when it has no further immediate benefit.

The United States consumes 30 percent of the world's energy although it has only 6 percent of the world's population. The high energy consumption has been associated with the high standard of living. The high rate of solid waste generation can also be related to the high standard of living.

As the volume of solid waste increases, economical disposal becomes increasingly more difficult. Open dumps and promiscuous dumping have extended into rural areas, creating a nuisance, a health hazard, and an area unattractive to the local residents.

This chapter presents an overview of the problem and discusses various methods for handling, storing, and disposing of solid waste material. Although various principles in designing a solid waste management system are discussed, SCS authorities and policies limit the assistance that can be provided municipalities and their consultants to inventory and evaluation (SCS Conservation Planning Memorandum 14).



This flow chart illustrates the simplest form of solid waste management that can normally be developed and forms the basis for this chapter.

This chapter does not discuss agricultural waste, which is covered in other chapters of this manual.

2. SOURCES AND COMPOSITION OF SOLID WASTE

A survey to determine the magnitude of the problem and the sources, generation rate, and composition of the solid waste material should be made before a plan for handling, collecting, and disposing of the waste is developed.

The sources and average quantities of solid waste generated in the United States are listed in tables 13-1 and 13-2, which were prepared from data collected in 1968.[1/]

Table 13-1.--Amount of solid waste produced in the United States

Source	Amount per year
	10^6 tons
Residential, commercial, institutional	250
Industrial	110
Mineral	1,700
Agricultural	2,280

Table 13-2.--Amount of solid waste produced per day

Source	Amount
	lb/capita/day
Household	1.14
Commercial	.38
Combined	2.63
Industrial	.59
Demolition	.18
Street	.09
Miscellaneous	.31
Total	5.32

Many authorities use a generation rate of 5.5 lb/capita/day, but it must be remembered that the rate in table 13-2 is based on the sources listed and that the actual rate may vary from place to place. A rural city that has little industry and light commercial activity may produce significantly less than the national average, or a city may have an urban development project that increases the amount of demolition and miscellaneous solid waste. The national average generation rate is expected to reach 6.5 to 7.0 lb/capita/day by 1980.

The composition of solid waste varies considerably from one area to another, and a survey of the solid waste produced in any one area

[1/] Data from Black, R. J., A. J. Muhich, A. J. Klee, H. L. Hickman, and R. D. Vaughan. National solid waste survey, an interim report. U.S. Dep. Health, Educ., and Welfare. 53 p. 1968.

is necessary to determine its actual composition. Some of the components of solid waste from municipal and industrial sources are listed in table 13-3 along with the general range in composition.

Note that the BTU value is in a range that may make self-supporting combustion possible. This value is particularly critical in designing incineration units or in recycling the heat for steam generation.

Table 13-4 lists the various components of solid waste along with some of the factors that influence the amount of the various components. Paper products are usually the largest component of solid waste.

AMOUNT OF SOLID WASTE

Municipal

Several attempts have been made to use mathematical models of the amount of solid waste generated, but often each model applies only to a particular area. The following factors affect increases in the amount generated:[2/]

1. An increase of 2 to 3 percent per capita per year is normal in solid waste generation. More disposable products are being produced.
2. The efficiency of the collection system determines the amount of solid waste to be disposed. As the efficiency of collection improves, the volume of solid waste increases.
3. The rate of urban development influences the rate of solid waste generation. The more densely populated an area becomes, the more solid waste is generated per capita.
4. Miscellaneous factors such as control of air pollution increase the amount of solid waste.

A New York City survey[2/] of solid waste generation by population density reported the following amounts of solid waste generated on the basis of population density:

Population density	Solid waste generated
Persons/mi^2	lb/capita/day
<500	3.4
500 to 12,000	1.54 log (density) - 0.68
>12,000	5.6

Commercial Establishments

The commercial area of a city produces a substantial volume of solid waste, but the amount varies with the kinds of establishments

[2/] Roy F. Weston Consulting Engineers. New York solid waste management plan, status report, 1970. EPA Report No. SW-5tsg. 250 p. 1971.

Table 13-3.--Composition of municipal solid waste[1/]

Component	Percentage by weight (wet basis)
Water	15-30
Carbon	15-30
Hydrogen	2-5
Oxygen	12-24
Nitrogen	0.2-1.0
Sulphur	0.02-0.1
Ash and metals	10-25
BTU	[2/]3,000-6,000

[1/] From Hickman, J. L., Jr. Characteristics of municipal solid waste. Scrap Age, Feb. 1969.

[2/] BTU value per pound.

Table 13-4.--Factors affecting composition of solid waste

Component	Percentage of total weight	Factors affecting composition
Metal	8-11	Percentage may decrease if a good recycling system for scrap iron is available and increase where industry uses large amounts of metal.
Glass	8-11	Percentage may decrease where there are local restrictions on nonreturnable bottles and increase where there are glass-related industries such as one making light bulbs.
Paper products	40-54	Usually the largest component; percentage may decrease if newspapers are sorted out and recycled (new deinking process encourages recycling) and where cardboard boxes are recycled as in some large warehouses.
Food wastes	10-25	Percentage is affected by local food-processing industries and whether feeding restaurant scraps to swine is prohibited as in some states.
Yard wastes	3-80	Percentage varies by season; often paying overtime or hiring additional help is required in summer.
Plastics	1-20	Percentage varies locally; affected by kind and amount of wrapping for products and plastic containers.
Cloth, rubber, leather, and synthetics	1-20	Percentage varies according to extent that local industry uses material.
Inerts	1-50	Percentage varies according to air-pollution abatement equipment used in industry and whether municipality uses an incinerator (ashes increase percentage). Urban renewal generates a high volume of inerts.

in the area. In one survey conducted in Cincinnati[3] solid waste generation of clothing, drug, grocery, and hardware stores, and restaurants were studied and the following mathematical model was developed.

$$
\begin{aligned}
\text{Solid waste generated} = {} & 19.36 \times \text{number of employees} \\
& + 145.90X \ (X = 1 \text{ for grocery stores; } X = 0 \text{ for other units}) \\
& + 5.20 \times \text{hours unit open per week} \\
& - 151.96Y \ (Y = 1 \text{ for drug stores; } Y = 0 \text{ for other units}) \\
& - 197.29
\end{aligned}
$$

This formula may not apply to other areas, but it illustrates the varying waste production, especially for grocery and drug stores.

Industrial

The method of collecting and transferring solid waste from industrial operations varies. Although each industry usually contracts for transfer of refuse, the municipal government may have to bear the expense for disposal. Table 13-5, based on the standard industrial code (SIC) and the solid waste generated per employee, may help in estimating the amount of solid waste produced by industry.

Table 13-5 reflects generation rates, but an investigation should be made to determine composition of the waste. Investigation may show that much of the material is recycled. Approximately 48 percent of solid waste is recycled within industry, but if wood industries are excluded, the waste recycled is approximately 28 percent.[4] More emphasis is being placed on recycling waste products, and the percentage of recycled industrial solid waste will probably increase.

Industrial solid waste is primarily from three sources--shipping, processing, and offices. More consideration must be given to the amount of waste generated by various air-pollution abatement systems, for these may considerably increase solid waste generation in some industries.

Agricultural

Although this chapter does not discuss agricultural waste, table 13-6 is included to show production rates for some solid wastes other than animal wastes.

3. STORAGE METHODS

Storage practices depend on the source of waste material--dwellings, commercial and institutional buildings, or industrial sites.

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[3] DeGeare, T. V., Jr., and J. E. Ongerth. Empirical analysis of commercial solid waste generation. Proc. ASCE Sanitary Engineering Division 97: (SA6) 843-850. 1971.

[4] Combustion Engineering, Inc. Technical-Economic study of solid waste disposal needs and practices. Prepared for U.S. Dep. Health, Educ., and Welfare. 410 p. 1969.

Table 13-5.--Production rate of industrial solid waste[2]

Activity No.	SIC	Industry	Waste produced
			ton/employee/year
1	201	Meat processing	6.2
2	2033	Cannery	55.6
3	2037	Frozen foods	18.3
4	Other 203	Preserved foods	12.9
5	Other 20	Food processing	5.8
6	22	Textile mill products	.26
7	23	Apparel	.31
8	2421	Sawmills and planing mills	162.0
9	Other 24	Wood products	10.3
10	25	Furniture	.52
11	26	Paper and allied products	2.00
12	27	Printing and publishing	.49
13	281	Basic chemicals	10.00
14	Other 28	Chemical and allied products	.63
15	29	Petroleum	14.8
16	30	Rubber and plastic	2.6
17	31	Leather	.17
18	32	Stone, clay	2.4
19	33	Primary metals	24
20	34	Fabricated metals	1.7
21	35	Non-electrical machinery	2.6
22	36	Electrical machinery	1.7
23	37	Transportation equipment	1.3
24	38	Professional and scientific instruments	.12
25	39	Miscellaneous manufacturing	.14

[1] From Roy F. Weston Consulting Engineers. New York solid waste management plan, status report 1970. EPA Report No. SW-5tsg. 250 p. 1971.

INDIVIDUAL DWELLINGS

The most common storage device for an individual dwelling is the regular 32-gal garbage can. Some areas require that household solid waste be stored in a disposable liner that fits inside the garbage can. Most municipalities have ordinances requiring tight-fitting lids and a container size limitation, usually 32 gal.

Some cities require that household waste be stored in disposable containers to facilitate collection efficiency. One study estimated that the collection time for a disposable bag was 6 seconds and the collection time for a reusable container (garbage can), 18 seconds.[5] These collection rates were based on picking up the material at the street curb. Some other considerations are:

[5] McElevee, W. C., and M. J. Wilcomb. Some effects of disposable plastic liners on refuse handling efficiency. J. Envir. Health 30(5): 501-09. 1968.

Table 13-6.--Production rate of agricultural solid waste[1/]

Activity No.	Category	Annual waste production rate
		ton/acre
	Fruit and nut crops:	
1	Class 1 (grapes, peaches, nectarines)	2.4
2	Class 2 (apples, pears)	2.25
3	Class 4 (plums, prunes, miscellaneous)	1.5
4	Class 5 (walnuts, cherries)	1.0
	Field and row crops:	
5	Class 1 (field and sweet corn)	4.5
6	Class 2 (cauliflower, lettuce, broccoli)	4.0
7	Class 3 (sorghum, tomatoes, beets, cabbage, squash, brussel sprouts)	3.0
8	Class 4 (beans, onions, cucumbers, carrots, peas, peppers, potatoes, garlic, celery, miscellaneous).	2.0
9	Class 5 (barley, oats, wheat, milo, asparagus).	1.5

[1/] Data from a California study cited in Salvato, Joseph A. Jr. Environmental Engineering and Sanitation, 2nd. ed., p. 393. Wiley-Interscience, New York, 1972.

Disposable containers	Reusable containers
1. Cost of liners is nominal but continuous and higher than the reusable container cost.	1. Cost is fixed to the life of reusable containers, which is less than that for disposable liners.
2. Liner protects garbage can from corrosion and accumulation of food particles.	2. Cans frequently damaged after repeated use.
3. Liner can be treated with a dog repellent.	3. Dogs seeking food scatter rubbish.
4. Street curb has a better appearance.	4. Noise in handling is disturbing.

Another study showed the difference in collection time between disposable and nondisposable containers when collected by one-man and two-man crews (fig. 13-1).[6/] Note that the difference in time for a one-man

[6/] U.S. Dep. Health, Educ., and Welfare. A study of solid waste collection systems comparing one-man with milti-man crews. (Prepared by Ralph Stone & Co., Inc.) 174 p. 1969.

crew is fairly constant, but the difference in time becomes divergent for the two-man crew as the number of items to be collected at each stop increases.

COMMERCIAL AND INSTITUTIONAL

The storage devices for commercial enterprises and institutions are often the 3- to 10-yd^3 bulk containers that can be lifted by a truck and hauled to a disposal site or lifted by a truck and dumped into the truck's compactor. The size of containers varies with the area serviced and the method of transportation or collection.

Some buildings, such as multistory apartment and office buildings, have a central chute system for collecting refuse from each floor and a compactor at the bottom of the chutes. The compactor system may be designed to compact the material in a heavy-duty paper bag or to hold the material in a reusable container. Compacted material naturally requires less storage space and can be transported with greater efficiency. A storage area is usually designated for bulky items such as stoves, discarded furniture, and the like.

If a storage system is designed for an office area, the system should be compatible with the workday generation of solid waste. If the storage system is for a multistory apartment building, the storage unit

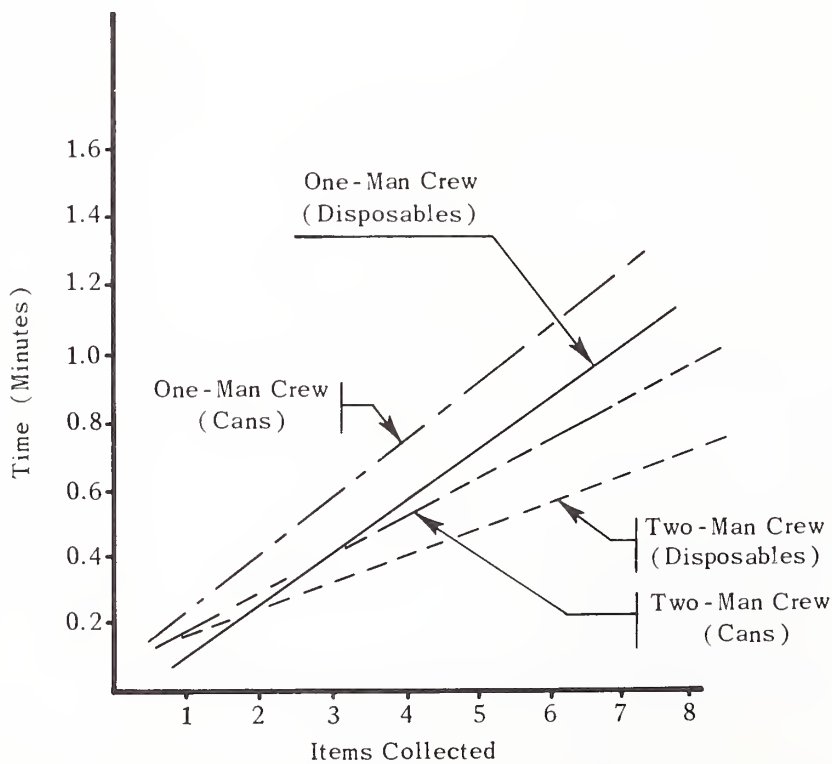

Figure 13-1.--Collection time for disposable vs. non-disposable containers by a one-man crew vs. a two-man crew.

should be designed to meet peak demands by hourly and daily fluctuations. In most apartment buildings the fluctuations are similar to those shown in figures 13-2 and 13-3.[7] The peak hourly generation is usually after 6:00 p.m., but the peak daily generation is on weekends. A storage system for solid waste should provide space for sanitary storage of waste during noncollection days, which are generally weekends.

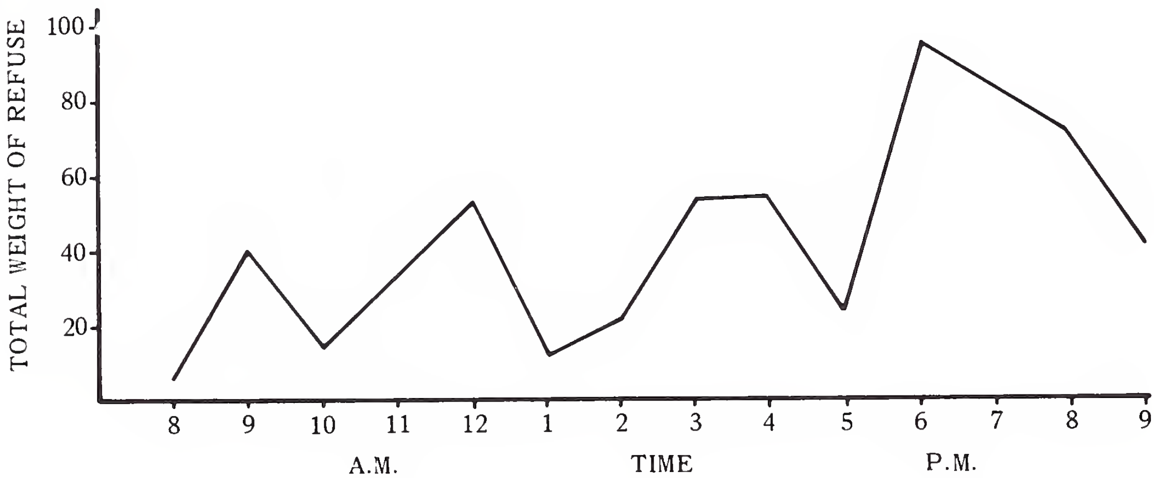

Figure 13-2.--Hourly solid waste generation in apartment buildings.

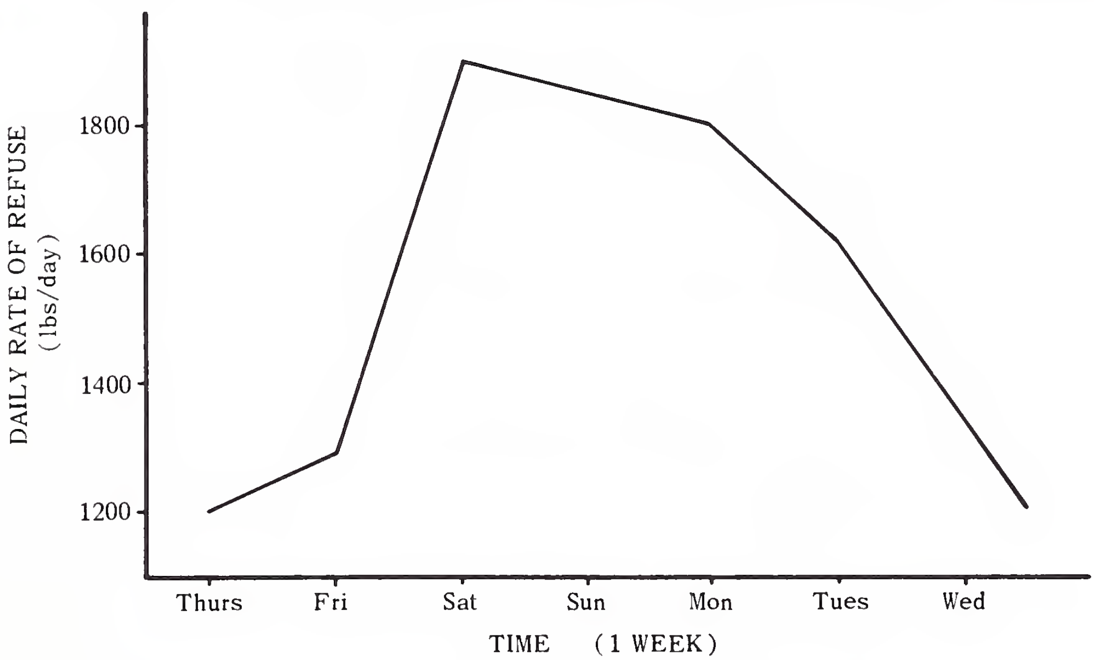

Figure 13-3.--Daily solid waste generation in apartment buildings.

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[7] From Kiefer, I. Solid waste management in high-rise buildings. EPA Report No. SW-27c1. 19 p. 1972.

INDUSTRIAL

The storage practices for industry vary according to the types of solid waste generated. Most industrial areas have some kind of disposal system and provide storage that is compatible with the system.

Industries that depend on a community disposal system usually have storage facilities similar to bulk containers. In some the nonputrescible bulky material, such as scrap iron, wooden crates, and the like, is placed in an open area for collection.

4. COLLECTION

Since the collection of solid waste usually consumes about 80 percent of a municipality's budget for solid waste management, the numerous factors that affect cost should be closely watched in the planning stages. These factors are:

1. Frequency of collection
2. Location of container
3. Climate
4. Topography
5. Population density
6. Type of equipment
7. Size of crew

FREQUENCY OF COLLECTION

Frequency of collection is based primarily on storage practices. For residential areas, it is better to collect the solid waste at least twice a week to reduce vector propagation. The incubation time for many vectors is at least 4 days and generally 5 to 7 days.[8] Removing the waste twice a week breaks the cycle and reduces the production of vectors in household garbage.

Onsite handling practices influence storage time and thus frequency of collection. Usually individual dwellings provide enough storage to meet the collection frequency selected for the area, but commercial and industrial areas require more frequent collections, once or twice daily, because of the volume of waste generated and lack of available storage.

Population density affects collection frequency. For example, an apartment complex usually requires more frequent collections because of the high generation rate in the confined area.

The 1968 national survey compared costs by collection frequency for household waste.[9]

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[8] Campbell, E., and R. J. Black. The problem of migration of mature fly larvae and its implication on the frequency of refuse collection. Calif. Vector Views 7(2). Feb. 1960.

[9] Black, R. J., et al. The national solid waste survey, an interim report. U.S. Dep. Health, Educ., and Welfare. 53 p. 1968.

Frequency of collection	Capital cost	Operating cost	Total cost
	$/ton	$/ton	$/ton
Once a week	0.75	4.85	5.60
Twice a week	1.15	5.67	6.82
Less than once a week (average of all surveyed).	0.53	4.86	5.39

LOCATION OF CONTAINER

The location of containers for an individual dwelling affects the cost of collection through time delays. Although various possible locations of containers and their acceptability to the dwelling occupants and collection crew can be compared, two locations are used for illustration.

Assume container location 1, behind a dwelling from which the crew collects the refuse, and location 2, behind a dwelling but the container is moved later to the street curb for collection.

Container location 1	Container location 2
1. Container is easily accessible to dwelling occupants.	1. Same as for location 1.
2. Occupant is not concerned with collection method.	2. Occupant must carry container to street curb for collection.
3. Esthetically, this is a good location since container is not visible from the street.	3. Esthetically, the container moved later to the street is not as acceptable as location 1.
4. Collection is more difficult than for location 2. Collection time is approximately 160 to 200 man-min/ton.[10]	4. Collection is easy. Collection time is approximately 100 man-min/ton.[10]

CLIMATE

The efficiency of a crew can be affected by inclement weather such as rainstorms or snowstorms. In areas that have much inclement weather the amount of solid waste collected per crew is usually reduced because mobility of equipment and personnel is impaired.

Yard and garden waste has a definite impact on the number of dwelling units serviced by a crew. The amount generated during nongrowing seasons is usually less than that during growing seasons. Figure 13-4 shows a general trend that can be expected for areas that have a growing

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[10] U.S. Dep. Health, Educ., and Welfare. A study of solid waste collection systems comparing one-man with multi-man crews. (Prepared by Ralph Stone and Company, Inc.) 174 p. 1969.

and a nongrowing season. Frequently extra crews are hired or overtime is allocated to cope with the increase in solid waste during the summer months.

TOPOGRAPHY

The effect of topography on collection cost is related primarily to mobility and maintenance of equipment. Areas of steep inclines decrease the speed of collection and increase maintenance cost, especially the cost of replacing vehicle clutches.

POPULATION DENSITY

The more densely populated an area, the higher the generation rate for solid waste. Figure 13-5 illustrates a general trend in cost of collection as related to population density. Type 1 area has a population density of 10 per acre; type 2, 11 to 20 per acre; type 3, 21 to 40 per acre; and type 4, 40 or more per acre.

The effect of population density on solid waste generation is further illustrated in the following comparison:[11/]

Population density people/mi[2/]	Solid waste generated lb/capita/day
10 to 200	2.4 to 3.1
200 to 2,000	2.8 to 3.8
2,000 to 7,000	3.2 to 4.5
7,000 to 10,000	5.0 to 5.5

The increase in solid waste generated (lb/capita) as related to the increase in population density is usually attributed to the increase in commercial and industrial wastes and street sweepings.

TYPE OF EQUIPMENT

Some variation in collection time can be attributed to the different types of equipment acceptable for collecting solid waste (fig. 13-6). Only those vehicles that are designed for this purpose can be classed as acceptable equipment. Open-bed trucks are not acceptable.

This graph was developed from a time-motion study of a one-man crew.[12/] Note that collection by a side-loading vehicle with right-hand drive is faster than that for either of the other two vehicles. These small vehicles are used to collect and transport household solid wastes to a larger compaction truck. To determine the most efficient vehicle, time-motion studies can be made of other types of collection vehicles.

[11/] Truitt, M. M., J. C. Liebman, and C. W. Kruse. Mathematical modeling of solid waste collection policies. U.S. Dep. Health, Educ., and Welfare. Report No. SW-lrg. 320 p. 1970.

[12/] See footnote 10.

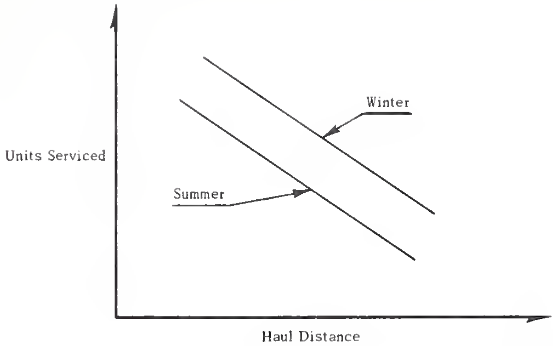


Figure 13-4.--Impact of season on units serviced.

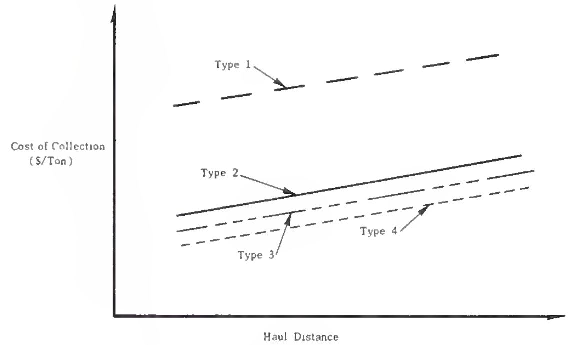


Figure 13-5.--Effect of population density on collection cost.

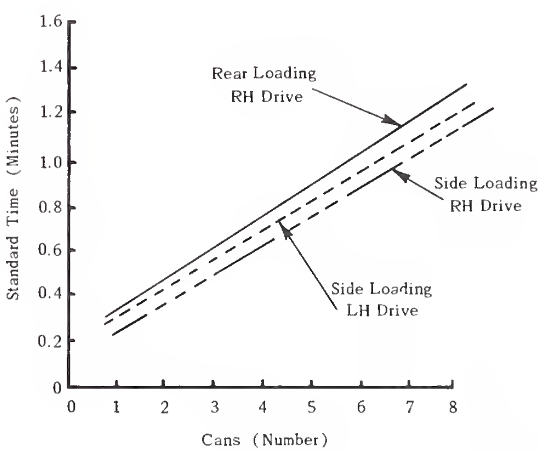


Figure 13-6.--Effect of type of equipment on collection time.

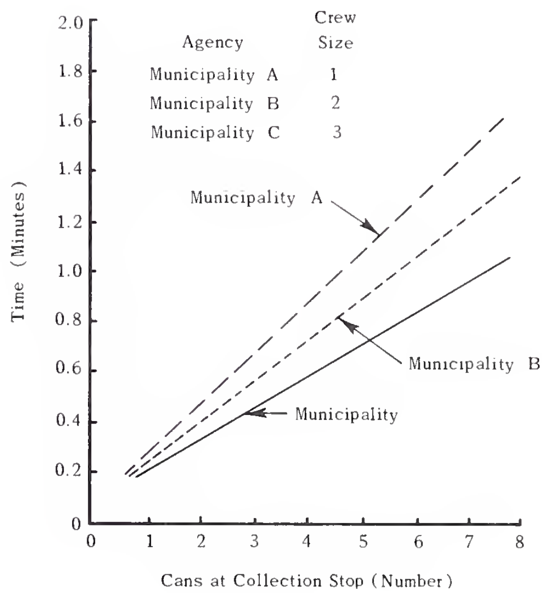


Figure 13-7.--Effect of crew size on collection time.

SIZE OF CREW

A large crew can collect more refuse than a smaller crew under the same conditions, but a crew can become too large to be efficient. It is generally accepted that a crew of two to three is about optimum.

Figure 13-7 illustrates the average collection time per stop for crews of three different sizes.[12/]

Note that the difference in time is not so significant for one container per stop as for seven or eight containers per stop; therefore, a one-man crew is not so inefficient for suburban areas as it would be for more heavily populated areas with more containers per stop.

5. MODES OF TRANSFER

COLLECTION ROUTE

Compactor trucks generally are used to transfer solid waste on a collection route. The refuse is unloaded by hand from a container into a section of the compactor and then pressed by a large piston unit to the opposite end of the compartment.

Satellite collection vehicles can be used in some suburban areas to collect refuse from individual households. These satellite vehicles are operated by one man. After the route has been completed or the body of the truck is filled, the refuse is emptied into a larger compactor truck. Several satellite vehicles are used for one compactor truck.

DIRECT HAUL TO DISPOSAL AREA

The most frequent mode of transferring refuse from the collection route to the disposal area is by direct hauling in the collection truck. This is particularly true for small municipalities that have a nearby disposal area. The collection crew is inactive during the time required to empty the contents of the truck, but this method is the most economical and manageable system for such small municipalities.

TRANSFER STATION

When the suburban areas around a city spread substantially, the haul distance to the disposal area increases. The increase in haul distance proportionally increases the expense of transferring the waste from the collection route to the disposal area. When the hauling distance to the disposal area exceeds 10 to 15 mi, a cost study should be made to determine the feasibility of another mode of transfer.

The most common system installed if hauling distance exceeds 10 to 15 mi is a transfer station. A transfer station receives the solid waste from the 12- and 20-yd^3 collection trucks, may process the waste to reduce the volume, and then uses another mode of transporting it to the disposal site.

A cost analysis of using a direct-haul system versus using a transfer station is shown in figure 13-8. At some haul distance the two lines cross and reflect the point beyond which it is more economical to use a transfer station. This point varies from area to area, but usually the haul distance is 10 to 20 miles.

[12/] See footnote 10.

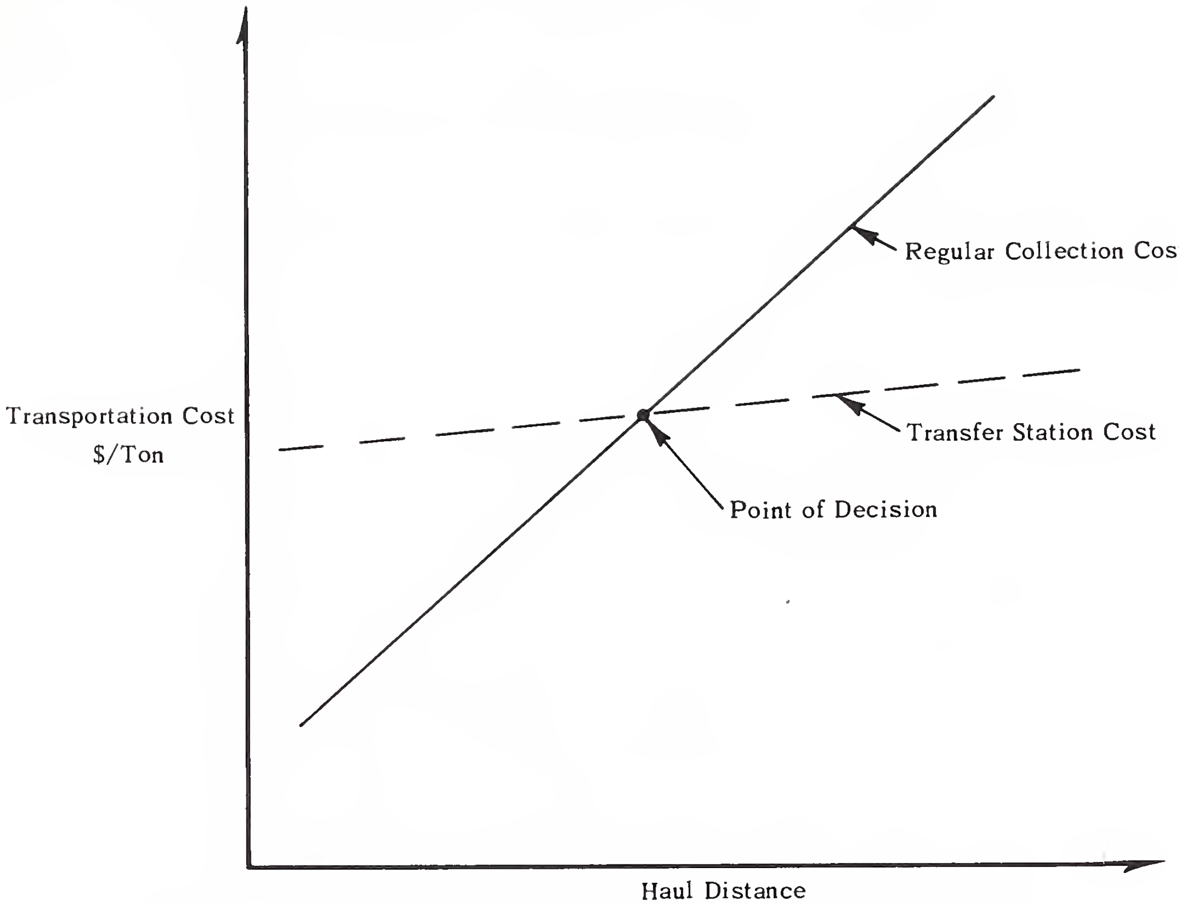
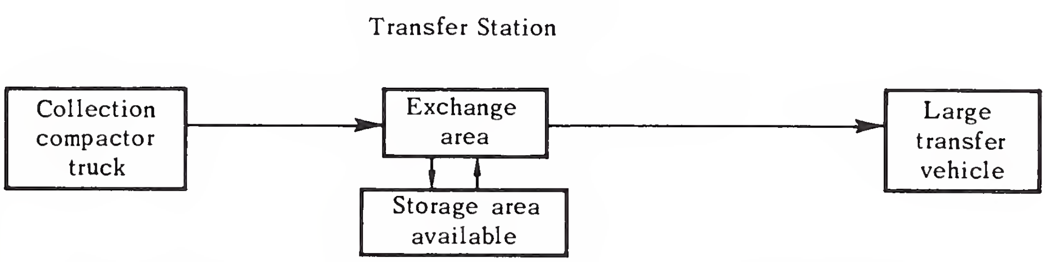


Figure 13-8.--Analysis of when to use a transfer station.

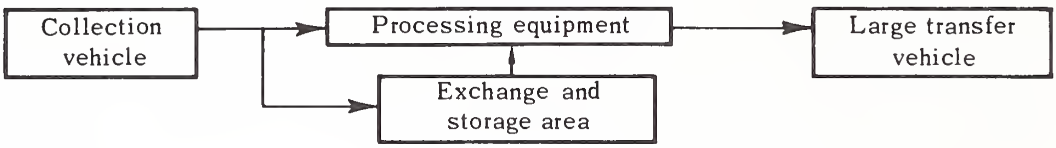
The transfer station may be simply a direct transfer of refuse from a 12- or 20-yd^3 collection truck to a 65-yd^3 compactor truck as follows:



Using a transfer station in this way is probably the least expensive to set up, but it may not be the most economical approach since the waste volume is not reduced significantly. The savings possible are related directly to the difference in transportation cost of the

collection compactor truck and a larger transfer vehicle. Some large transfer vehicles used in connection with transfer stations are large highway compactors (65 yd^3), rail cars, and barges (ocean dumping is restricted).

Most transfer stations have some type of processing equipment to reduce the volume of refuse. The general procedure follows:



Some types of processing equipment are:

Compactor.--The volume of solid waste is reduced by further compaction of the material received from the collection vehicle. The compacted material is usually bound into bales. A compactor is the most common processing equipment used because of the low fixed cost and the fairly low cost for operation and maintenance. The volume reduction depends on the compaction pressure and on the composition of the solid waste (table 13-7). High-pressure balers are being developed to bind large quantities of solid waste into bales without strapping. The optimum pressure is approximately 2,000 psi for 15 to 20 seconds. A baler with this pressure can get an 18 to 1 volume reduction.

Separator and pulp machine.--The metal and glass are removed by various means in a separator, and the remaining material is transformed into a liquid slurry, which is then dewatered, leaving a pulp. The material from the separator is recycled to reduce the volume of the solid waste. The pulping process needs some refinement, primarily because the increase in moisture content increases the cost of handling and hauling.

Incinerator.--The solid waste is incinerated and the ash and inerts are hauled to the disposal area. Because of the air-pollution abatement requirements, this approach is expensive and usually can be followed only in large metropolitan areas.

Table 13-7.--Weight of refuse by kind of processing[1/]

Processing	Weight
	lb/yd^3
Loose refuse	125-240
Compacted in refuse truck	300-600
Shredded and compacted	1,600
Compacted and baled	1,600-3,200
Compacted in apartment compactor	700

[1/] Salvato, Joseph A., Jr. Environmental engineering and sanitation. 2nd ed. p. 398. Wiley-Interscience, New York. 1972.

In selecting a site for a transfer station both appearance and operation should be considered. The site should be about the optimum distance from the collection routes and the disposal site. Good access roads are necessary. Although the station should be adjacent to a highway, it should be relatively isolated or hidden. Transfer stations are often near commercial areas. The transfer station should have an adequate loading and unloading area and should provide adequate storage during periods of peak demand. Most transfer stations have a sprinkler system for protection against fire. The sprinklers are also used for odor control.

6. DISPOSAL

Methods of disposal include open dumps, composting, burial at sea, sanitary landfill, feeding to hogs, incineration, grinding and discharging to a sewer, anaerobic digestion, pyrolysis, and wet oxidation. The primary emphasis in this section is on sanitary landfills and composting.

OPEN DUMPS

Open dumps are prevalent, especially in small rural communities. Refuse usually is spread over an open area by individuals or a collection crew and becomes a harbor for rats, flies, and other vermin. An open dump is unsightly, fires burn, and surface runoff from the site is polluted. Open dumps should be discontinued and sanitary landfills installed.

BURIAL AT SEA

Coastal towns at one time used barges to tow refuse to the sea, where it was dumped at a distance that would prevent it from being washed back to shore. Recent federal legislation imposes severe restrictions on burial of refuse at sea, and the practice is being discontinued.

The use of high-density bales in Japan has received favorable attention. The bales have a density of 70 to 109 lb/ft^3, sink in sea water, resist corrosion, have good structural cohesiveness, are reasonably free of odor, and show no anaerobic or aerobic decomposition. This system has not been attempted in the United States.

HOG FEEDING

The feeding of food waste from large food-processing establishments to swine has presented numerous health problems. The spread of trichinosis to man and of hog cholera and foot-and-mouth disease in swine is encouraged when swine are fed uncooked garbage.

Federal interstate quarantine regulations require that garbage be cooked before it is fed to swine. Most states have the same requirement. Some states have outlawed the feeding of garbage to swine

because of the difficulty of enforcing the cooking requirement. For proper cooking the garbage must be boiled continuously for 30 minutes.

GRINDING AND DISCHARGING INTO A SEWER

Although a homeowner considers putting food wastes through a household garbage grinder convenient, the material flows into a sewer and must be treated at a sewage treatment plant. The material does not affect the sewer system, but it increases the organic load to the waste treatment plant; 70 to 75 percent of the material settles out into the primary sludge.

The use of garbage grinders increases the water supply requirements about 0.5 gal/capita/day. The cost of disposal via waste treatment plants is 50 to 100 percent more per ton of garbage than the cost of collection, transportation, and burial. A survey of communities on the use of garbage disposals showed that 50 percent of the communities had no requirements, 25 percent required garbage grinders, and 25 percent banned their use.[13/]

One of the primary public health benefits of using garbage grinders is the prompt removal of putrescible matter from a dwelling, thereby eliminating sources of odor and food for rats, flies, and other vermin. The necessity of twice-a-week garbage pickups for vector control is reduced, which could reduce the collection cost.

ANAEROBIC DIGESTION

For anaerobic digestion, metal, glass, and nondecomposable materials are separated from the refuse. The remaining decomposable material is ground and then digested at a controlled temperature in the absence of air. The resultant gases are mostly methane and carbon dioxide, and the residue can serve as a soil conditioner. Anaerobic digestion for solid waste is still in the experimental stage.

PYROLYSIS

Another experimental process is pyrolysis, a thermochemical process for converting complex organic solids in the absence of free oxygen. This process of destructive distillation under temperatures of 1,000° F to 2,000° F is similar to that used for making charcoal. For refuse, the end products are carbon, water, carbon dioxide, acetic acid, acetone, oil and tar residue, and various inerts.

[13/] Watson, K. S. Water requirements of dishwashers and food waste disposers. J. Amer. Water Works Assoc. 55(5); 555-60. 1963.

The capital cost of a 150 ton/day plant is about $8,000,000 and the operating cost, $5.70 per ton.[14] In theory, the plant could receive a return on the recovered byproducts as follows:

Item	Percent of refuse	Ton/day	Unit price ($/lb)	Revenue ($/day)
Acetone	0.3	0.45	0.065	58
Acetic acid	3.1	4.65	.09	837
Oils and tars	12.0	18.0	.01	360
Charcoal	25.0	37.5	$7.00/ton	262
			Total	$1,517/day or $10/ton

INCINERATION

A properly designed and operated incinerator can function satisfactorily for the combustible materials in the refuse, but the system must also meet the requirements for air-pollution abatement. To be efficient and to prevent excessive odor and air pollution the incinerator should operate 6 or 7 days a week at controlled high temperatures. The operating temperature in the furnace usually ranges from 2,100° to 2,500° F. and the temperature of the gases leaving the furnace from 1,400° to 1,800° F.

It is usually recommended that a 3-day storage bin be provided for storage during shutdown of the furnace and to have enough refuse for continuous operation. Past experience generally indicates that incinerators are not economical for communities with population of less than 50,000. With the increasing demands for air-pollution abatement the community probably will have to be even larger to justify expenditure for an incinerator.

Nonincinerable and bulky refuse, such as demolition waste, street cleanings, abandoned appliances, and the like, may be 20 to 30 percent of the total weight of refuse collected. Residue from the incinerator as well as the nonincinerable waste must still be disposed in some way, usually in a landfill. The incinerator serves primarily to reduce volume. The residue is usually 15 to 25 percent of the original weight and 10 to 20 percent of the original volume. In the following example two disposal systems are compared for volume reduction--1, incineration followed by disposal in a sanitary landfill, and 2, disposal in a sanitary landfill without incineration.[15]

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[14] Drobny, N. L., H. E. Hull, and R. F. Testin. Recovery and utilization of municipal solid waste. EPA Report No. SW-10c. 118 p. 1971.

[15] DeMarco, J., D. J. Keller, J. Leckman, and J. L. Newton. Incinerator guidelines. U.S. Dep. Health, Educ., and Welfare. 98 p. 1969.

	Original unit volume		Reduction factor		Final unit volume
System 1:					
Incinerable waste	0.8	x	0.0145	=	0.0116
Nonincinerable waste	0.2	x	0.5	=	0.10
				Total	0.1116
System 2:					
Incinerable waste	0.8	x	0.166	=	0.133
Nonincinerable waste	0.2	x	0.5	=	0.10
				Total	0.233

Note that the volume remaining after incineration and compaction in a sanitary landfill as in system 1 is about half that remaining after compaction of the original unit volume in a sanitary landfill as in system 2. A twofold reduction in remaining volume seldom justifies the cost of incineration. This further illustrates why the use of compactors is widespread, even at large transfer stations.

The cost of incineration usually ranges from $8 to $14 a ton, but the cost can be reduced by selling the heat to electric-power generating plants or by recycling some of the residue. The residue from one incinerator[16/] had the following composition: fines, 52.6 percent (by weight); unburned combustibles, 1 percent; metal, 20 percent; and glass and other inerts, 26.4 percent.

COMPOSTING

Composting is the aerobic thermophylic decomposition of organic material to a relatively stable humus material. The temperature of the mass of organic material is usually above 45° C. If the mass is not stirred frequently for aeration, the aerobic decomposition can shift to an odorous anaerobic condition.

The microbial action in the organic mass is affected by temperature, moisture, aeration, and the organic composition. Figure 13-9 illustrates the temperature rise as it is related to the number of micro-organisms and time. The temperature peak varies with the various processes and environmental factors, but the range is usually between 130° and 175° F. The peak is usually reached in 2 to 7 days and is usually maintained for 3 to 5 days.

The action of the micro-organisms also affects the pH of the organic mass (fig. 13-10). The pH drops as the temperature of the mass increases and increases as temperature falls. One test used to check

[16/] Achinger, W. C., and L. E. Daniels. An evaluation of seven incinerators. EPA Report No. SW-51tslj. 52 p. 1970.

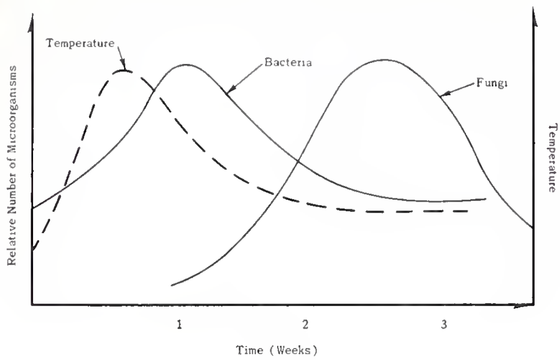

Figure 13-9.--Temperature vs. number of organisms in compost and time.

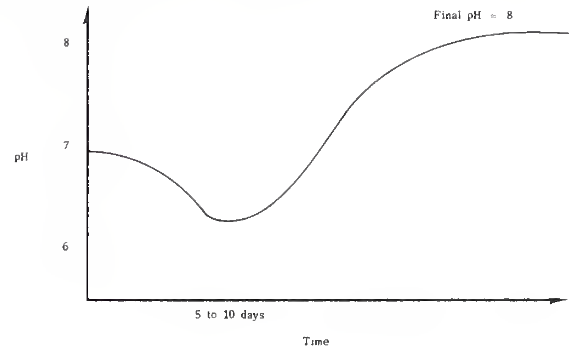

Figure 13-10.--pH value of compost vs. time.

completion of the composting process is to incubate the material in an anaerobic condition for 24 hours and then check the pH.[17] The process is complete when the pH exceeds 7.0.

Active composting requires 7 to 12 days, and curing time is 2 to 6 weeks.

Some other factors affecting the composting process are:

1. Moisture content should be greater than 40 percent; the optimum range is between 50 and 60 percent.
2. The mass should be turned or rotated frequently to maintain aeration for odor control.
3. The mixture should be heterogenous, which usually requires grinding and mixing of the refuse.
4. Materials that cannot be composted should be removed from the refuse.

Table 13-8 gives an idea of the costs for various methods of processing and disposal. These costs vary considerably from one location to another, but various recycling systems can be used to reduce these costs.

SANITARY LANDFILL

Disposal of waste in a sanitary landfill is the most popular acceptable method in the United States. A sanitary landfill permits orderly spreading and compacting of refuse and daily covering with soil, without open burning or other environment-damaging problems. A sanitary landfill has often been considered the only true final disposal since the residue from many of the other processes is disposed in landfills.

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[17] Jann, C. J., D. H. Howard, and A. J. Sulle. Method for the determination of the completion of composting. Applied microbiology 7(5): 271-275. 1956.

Table 13-8.--Summary of disposal and processing costs[1/]

Method	Cost
	$/ton
Collection	10.00 to 13.00
Sanitary landfill	1.00 to 3.50
Open dump[2/]	0.50 to 2.00
Incineration	8.00 to 14.00
Composting	8.00 to 25.00
Marine disposal[2/]	4.00 to 6.00
Compaction	1.00 to 2.00
Shredding	2.00 to 4.00

[1/] From Salvato, Joseph A., Jr. Environmental engineering and sanitation, 2nd ed. p. 408. Wiley-Interscience, New York. 1972.

[2/] Not acceptable.

England originated the sanitary landfill in 1916, calling it "controlled tipping." The United States had two sanitary landfills in the 1930's, one in New York City and the other in San Francisco, Calif. In 1968 there were 6,500 sanitary landfills.

Most states or local governments have regulations that require their review and approval of plans for sanitary landfills before projects are begun. This authority is often necessary to protect the well-being of the local populace and insure the adequacy of the proposed system.

Many governing districts have legal restrictions in zoning and codes that prohibit landfills in certain areas. Many governing units and municipalities are developing regional or countywide solid waste collection with a central disposal area to reduce cost and overcome zoning obstacles. But where open dumps have been the prevailing method of disposal it is often difficult to overcome public opposition to replacing them with sanitary landfills.

Some of the items that must be considered in designing a sanitary landfill are discussed in the following pages.

Area of Landfill

The first consideration should be determining the area needed for the landfill. To do this the designer must have some idea of the volume of waste collected daily. These data may be available from past records of the collection operation or from a solid waste survey of the area.

A rule of thumb often applied is 1 acre/10,000 persons/year, but this formula may not always apply to a particicluar area because of variables such as per capita solid waste generation, degree of compaction, and depth of burial.

The American Public Works Association has a formula that more accurately projects the volume required for a landfill. This formula is:

$$V = \frac{27 \times F \times R}{D} \times \left(1 - \frac{P}{100}\right)$$

where

V = Volume required in yd^3/capita/yr
F = Factor related to the depth of fill:
1.17 for deep fills (over 15 ft deep)
1.33 for shallow fills (less than 15 ft deep)
R = Amount of refuse generated (lb/capita/yr)
D = Delivered density (lb/yd^3)
P = Percent reduction in volume of fill due to compaction (ranges from 0 to 70 percent but should be from 30 to 50 percent)

The best method is to compute the yearly refuse collected, project the future amount of refuse to be collected, select the design life of the facility (may be from 10 to 50 years), and, using a topographic map, calculate the area required.

Length of Haul to Sanitary Landfill

The haul distance should be minimized to reduce the haul cost. Often municipal officials try to get away from the municipality or congested areas to locate a landfill on less expensive land. Because of the distance, a transfer station to help reduce the haul cost may be necessary. A thorough analysis may show that it is more economical to purchase more expensive land near the major waste source than to haul the waste or build a transfer station. Figure 13-11 illustrates the analysis necessary for selecting the optimum distance to the sanitary landfill.

Future Land Use

An appealing aspect of sanitary landfills is that the area can be reused after the landfill has been closed. The uses most popular are parks, golf courses, playgrounds, etc. A closed landfill should not be used for extensive building unless the foundation extends below the compacted refuse. Danger of explosive gases must also be considered. If the future use of the area is known, then the final landfill grade can be designed to be the grade desired for the planned use, thus eliminating further construction work.

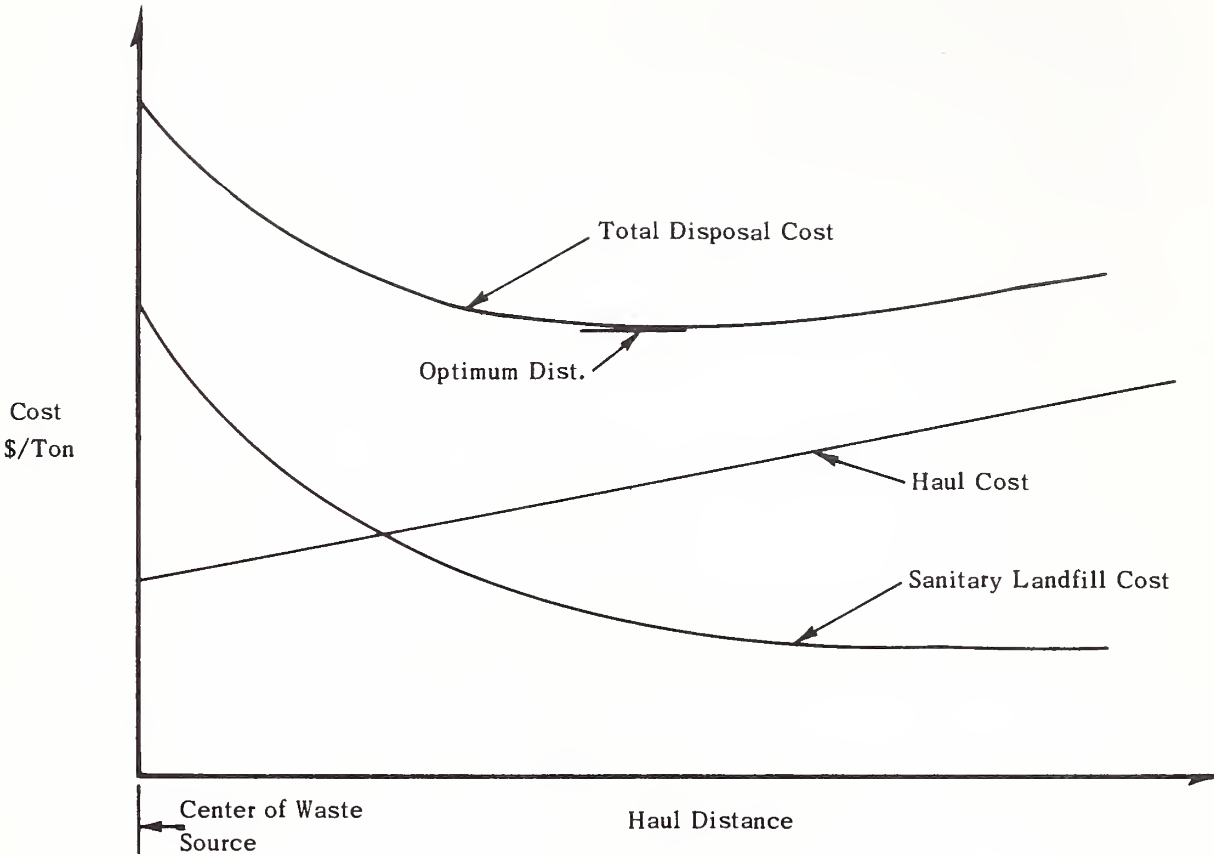

Figure 13-11.--Analysis of distance to landfill vs. cost.

Drainage

Drainage is one of the primary factors to consider in the layout of a landfill, especially in high rainfall areas. All surface drainage should be diverted from the operating face of the landfill to reduce erosion of the earth cover and removal of refuse from the site. Special precautions for adequate drainage should be taken in low, flat areas so that there will be no ponding of water.

Soil Characteristics

The primary criterion of soil is its workability. Many other characteristics of the soil, especially permeability, should be considered, but the primary emphasis is usually given to workability because of the earthmoving necessary. Guide sheets 7, 8, and 9 of the SCS guide for interpreting engineering uses of soils provide information on the suitability of soils for sanitary landfills (see chap. 5).

Table 13-9.--Suitability of general soil types as cover material*
[From EPA publication listed in footnote 18]

Function	Clean gravel	Clayey-silty gravel	Clean sand	Clayey-silty sand	Silt	Clay
Prevent rodents from burrowing or tunneling.	G	F-G	G	P	P	P
Keep flies from emerging.	P	F	P	G	G	E+
Minimize moisture entering fill.	P	F-G	P	G-E	G-E	E+
Minimize landfill gas venting through cover.	P	F-G	P	G-E	G-E	E+
Provide pleasing appearance and control blowing paper.	E	E	E	E	E	E
Grow vegetation.	P	G	P-F	E	G-E	F-G
Be permeable for venting decomposition gas.‡	E	P	G	P	P	P

* E, excellent; G, good; F, fair; P, poor.
\+ Except when cracks extend through the entire cover.
‡ Only if well drained.

Table 13-9, which lists other soil characteristics that should be considered in planning a landfill, has been taken directly from an EPA publication on sanitary landfills.18/

Protection of Ground Water

Special precautions must be taken to be sure that the landfill will not cause pollution of ground water. A geological investigation is often necessary to determine the subsurface conditions. Some state regulatory agencies require deep subsoil investigation and submission of the boring logs with the proposed plans for the landfill. The soil survey of the area can be used to good advantage in making preliminary investigations for locating possible sites, but any proposed site should be studied by a geologist and deep subsoil borings made if he believes it necessary. Table 13-10 summarizes a case study of the effect on water quality where a landfill intercepted the water table. The soil was a sandy loam.

The primary effect on water quality was the increase in total dissolved solids. Levels of all the parameters were increased, which could become a problem to downstream water quality. If possible, the landfill should be moved to avoid areas where pollution of ground water could result. It could be that precautions initiated when the landfill is first put into operation will be discontinued 10 or 15 years later.

18/Brunner, Dirk R., and Daniel J. Keller. Sanitary landfills design and operation. EPA Report No. SW-65 ts. 59 p. 1972.

Table 13-10.--Quality of ground water[1/]

Characteristic	Well upstream	Landfill	Well downstream
	mg/l	mg/l	mg/l
Total dissolved solids ...	636	6,712	1,506
Chemical oxygen demand ...	20	1,863	71
Total hardness	570	4,960	820
Sodium	30	806	316
Chlorides	18	1,710	248
pH	[2/] 7.2	[2/] 6.7	[2/] 7.3

[1/] This table taken from p. 6 of publication listed in footnote 18.
[2/] pH value.

Sealing

In areas of limestone or rock crevices the usual precaution is to seal the bottom of the landfill with a well-compacted soil of sufficient clay content for seepage control. If a trench-type landfill is used, the sealant should be installed after the excavation is complete. Mounding refuse above the surface rather than excavating the soil above crevices may reduce the potential for ground-water pollution. The site may still require a soil blanket if the layer of soil above the crevices is moderately permeable. Some states specify the minimum soil depth required between the refuse and the ground water at its highest elevation.

Subsurface Drains

A system of subsurface drains can be used if excavation for the landfill trenches intercepts the water table. A soil layer over the drains protects the drain pipes and insures a water table sufficiently lowered. Figure 13-12 illustrates use of subsurface drains to lower the water table.

Pump Systems

Pump systems have been used extensively in construction work for dewatering or lowering the water table. Pumps can be used for the same purpose on a sanitary landfill, but the cost probably is excessive if the system is required on a continuous basis. If the system is to be used only during high fluctuations of the water table, the cost may not be prohibitive.

Climatic Conditions

A sanitary landfill should be designed to operate during all seasons and throughout every workday. All-weather roads should be constructed to and on the landfill site, cover material should be

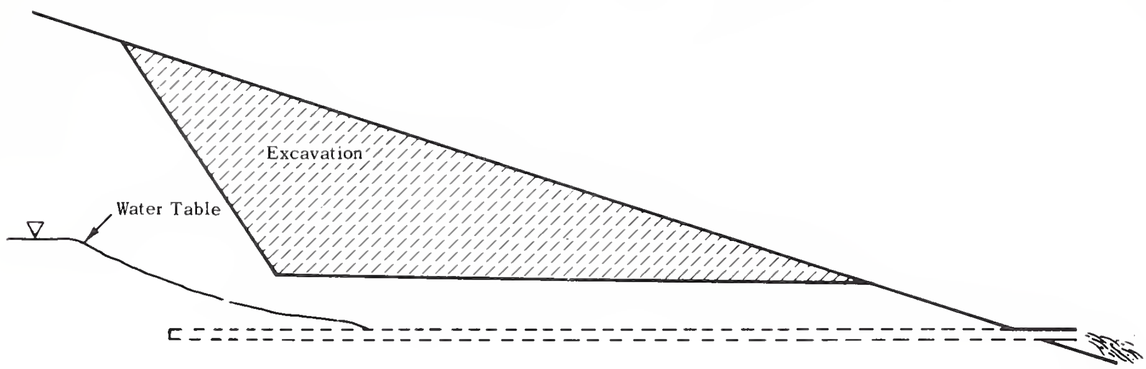

Figure 13-12.--Water-table control with subsurface drains.

stockpiled for use during inclement weather, the landfill area should not be in danger of flooding, and shelter should be provided for the landfill personnel.

Site Survey

To design a landfill, both a good topographic map and records of soil borings are essential. Although various methods of disposal in a landfill are used, area-type and trench-type sanitary landfills are the most common.

The area method uses the existing natural slope of the land. The refuse in the collection truck is deposited at the site, and the landfill equipment moves the refuse to the working face of the fill, which is usually kept small to control scattering.

In the trench method a trench, usually less than 150 ft wide, is excavated. The refuse is deposited over the edge of the trench and spread on the slope for compaction. The daily accumulation of refuse is covered with at least 6 inches of compacted earth that was excavated for the trench. Both intermediate and final cover materials may be from the surrounding soil material, or they may be hauled to the site from a nearby borrow area.

All sanitary landfills should have at least 2 ft of compacted earth as the final cover. For some uses planned for the area after it is no longer used as a landfill, a deeper cover may be advantageous, e.g., areas to be used for growing row crops need approximately 4 ft of cover.

The cost of a landfill is determined by the cost of the land, equipment, initial land alterations, and installation of various facilities such as scales, office and maintenance buildings, fencing, paving,

etc. Usually, large landfill operations are more efficient than smaller ones (see fig. 13-13). The cost factor is important in rural disposal systems, which are discussed later in this chapter.

Other items that should be considered when planning a sanitary landfill are area policing, equipment selection, insect and rodent control, maintenance program, and operation control.

7. RURAL DISPOSAL

Disposal of solid waste in rural sections is a serious problem. Not only is promiscuous dumping along country lanes unsightly but it also contributes to the propagation of various vectors. Storm runoff from these areas may increase the possibility or water pollution. The problem is increasing because of the growing development of rural areas near cities.

Several attempts have been made by local citizens to cope with the problem, but most of the plans have failed. If the population density is high enough, contracting for a commercial firm to collect waste at individual dwellings may be practical.

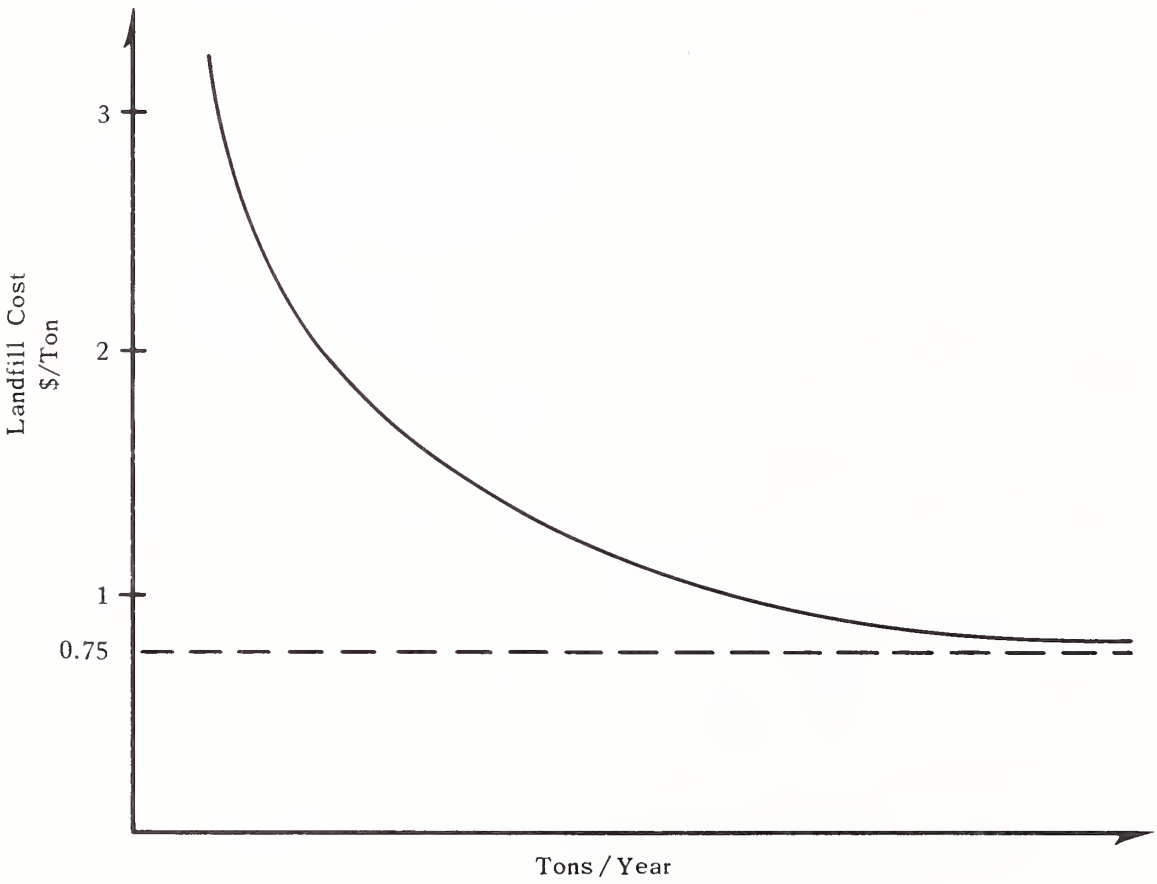

Figure 13-13.--Landfill cost vs. size of operation.

If a county is too sparsely populated for dwelling-to-dwelling waste collection, another approach is constructing a series of landfills over the county, generally called community landfills. The governing body for the county arranges for cleaning the area and covering the solid waste, usually once a week. Some of the disadvantages of this disposal system are:

1. If some members of the governing body are not reelected, routine maintenance may be discontinued, especially during the construction season.
2. Users of the landfill often do not throw the refuse directly into the landfill, and within a few days the refuse is scattered over the terrain.
3. The pile of uncovered refuse is a prime area for vector and vermin propagation.
4. Refuse is often burned, polluting the air and creating a fire hazard to the surrounding vegetation.
5. Maintenance of the numerous landfills may be much more expensive than anticipated.
6. Because the refuse is not covered daily, such community landfills are not sanitary landfills.

For these and other reasons, community landfills for disposal of solid wastes have not been successful in most areas.

County-wide collection systems have been promoted in recent years. Large containers (2 to 5 yd^3) are placed over the county on major transportation arteries. The containers are emptied twice a week into a compactor truck with special attachments that lift the containers and dump the contents into the body of the truck. The truck driver can operate the lift system from the driver's seat. The truck services several containers and then goes to a centrally located sanitary landfill. Most counties need only one sanitary landfill to serve both the county population and local towns. Usually a county can operate one sanitary landfill properly and economically. Figure 13-14 illustrates this approach.

Countywide collection systems appear fairly successful, especially if the citizens (1) are well informed about the system, (2) recognize the benefits of cleaning up the dumping sites, and (3) have easy access to the containers adjacent to the main transportation routes. The entire plan should be publicized through all available media and through meetings with schools, clubs, organizations, and the like. When the system is first initiated, all the local citizens may not use the containers, but with continued promotion participation usually is nearly 100 percent in 6 to 10 months.

8. CONCLUSION

Any attempt to develop a waste disposal system should be discussed with the state regulatory agency before promoting the system at the local level. Many regions have restrictions peculiar to the area. The regulatory agency is aware of these restrictions and can provide valuable service to the planning organization that will avert later embarrassment.

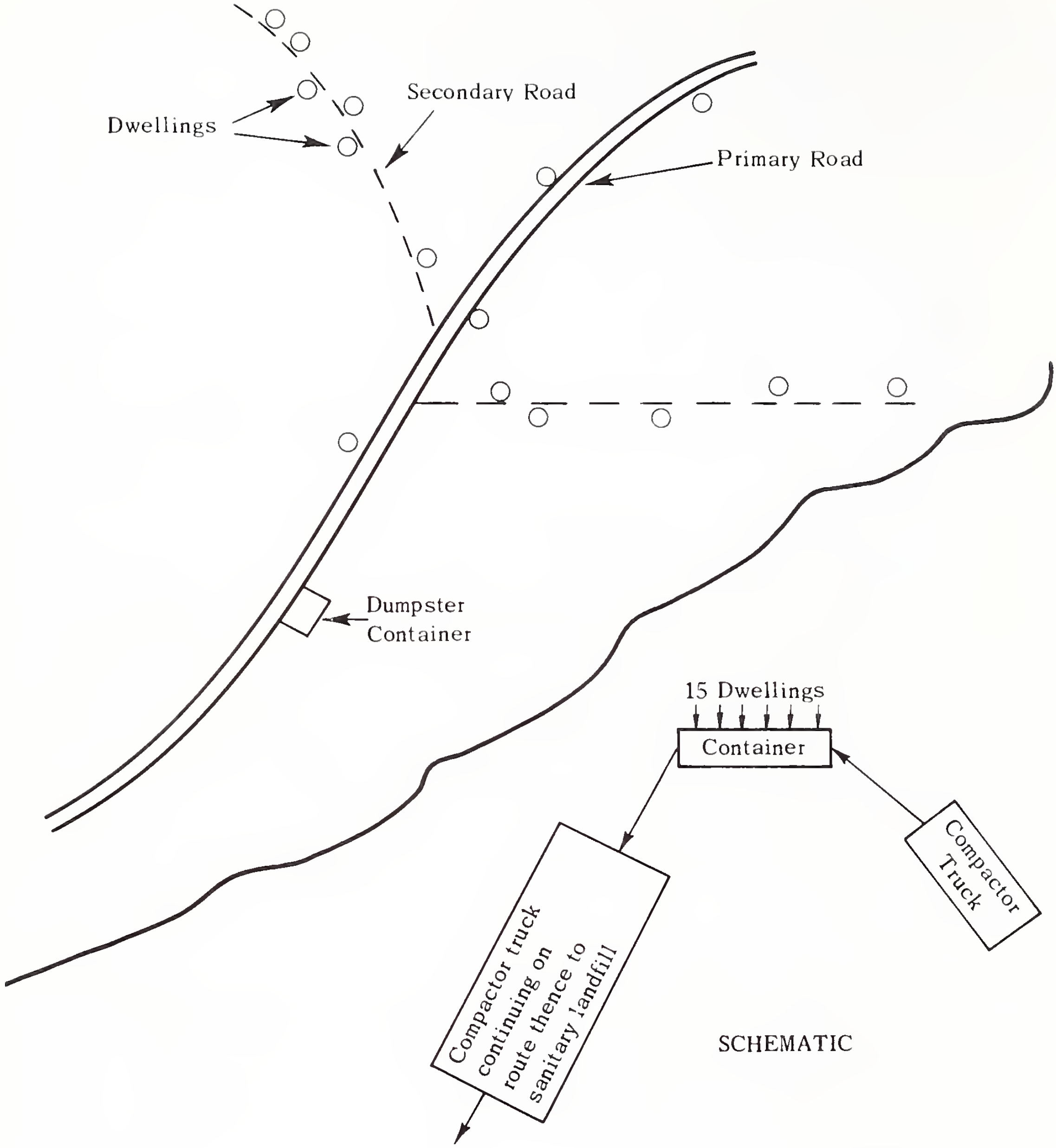

Figure 13-14.--Segment of a county-wide collection system.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 14. PESTICIDES AND OTHER CHEMICALS

Compiled by Joseph W. Turelle, chief agronomist (ret.), SCS, Washington, D.C.

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CHAPTER 14. PESTICIDES AND OTHER CHEMICALS

1. INTRODUCTION

The impact of pesticide use in the United States is tremendous. Commercial pesticides comprise some 300 individual compounds that are applied to field crops, vegetables, and food that is processed and stored and to soil and water. In 1969, according to the U.S. Tariff Commission, 983 million pounds of herbicides, insecticides, and fungicides were sold in the United States. Each year herbicides are used on 140 million acres of cropland (estimated) and insecticides on 90 million acres.

Pesticides combat certain diseases transmitted to man, improve animal health, and increase the quantity and quality of foodstuffs, timber, and ornamental plants. Emphasis on the use of pesticides in soils and water and on plants is likely to increase in the future. Newer compounds undoubtedly will be formulated for high biological activity, selectivity, soil absorption, movement, and persistence.

But pesticides, the chemical compounds used in controlling insects, micro-organisms, and the proliferation of vegetation, can have adverse effects. Herbicides, insecticides, and fungicides are the pesticides commonly used in agriculture. Nematocides and rodenticides are of relatively less importance. Soil is the ultimate sink for most widely used pesticides.

2. BEHAVIOR OF PESTICIDES IN SOILS

Once pesticides are introduced into the environment, outside forces immediately begin acting on them. Six transfer processes are important in determining what happens to pesticides in the environment: adsorption by soil particles, absorption and exudation by plants, retention in plants, leaching, volatilization, and runoff.

The most significant influence on pesticides in soils is adsorption.[1/] The quantity and kind of clay and organic matter, surface area, cation-exchange capacity, soil structure, water content and quality, temperature, and pH are factors that affect the distribution of pesticides between soil particles and the surrounding water or air. The degree of adsorption is usually in this order: organic matter > high-charge clays > low-charge clays. Pesticide characteristics such as chemical makeup, structure, water solubility, charge distribution, and molecular size also affect adsorption.

Pesticides can penetrate through tissues into an organism (absorption), or they can be discharged from inside an organism to the

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[1/] Hellings, Charles S., Philip C. Kearney, and Martin Alexander. Behaviour of pesticides in soils. Adv. Agron. 23: 147-240. Academic Press, N.Y. 1971.

surrounding environment (exudation). Retention in vegetation followed by transfer in the harvested product is another transfer process.

Movement of pesticides occurs within and through the soil and along and away from the soil surface through leaching, volatilization, and runoff. Leaching consists of two processes, molecular diffusion and mass transfer. Diffusion occurs in both soil water and air but is significant for only a few centimeters. It is governed by inherent diffusion properties, soil structure, soil water content, and adsorptive capacity of the soil particles for the pesticide. Movement of pesticides is greatest in light-textured soils that are low in organic matter and clay.

Volatilization depends on the chemical characteristics of the pesticide, soil texture, soil water content, soil adsorptive capacity, temperature, and pH. Volatilization is increased by high temperatures and low clay or organic matter content. Volatilization losses are usually greater from moist soil than from dry soil. Gaseous diffusion within soil becomes negligible as pores become water saturated. Surface loss is decreased by soil incorporation, compaction, or sealing.

Pesticides most likely to be lost in runoff are those not inherently mobile. Movement of pesticides across a soil surface is increased by steep slopes, low soil permeability, and wind and water erosion.

The importance of pesticide degradation by direct light (photodecomposition) is uncertain. Since photodecomposition occurs only at the soil surface, those compounds not incorporated in the soil or those that have moved to the surface may be degraded by direct light.

Degradation of pesticides in soils may be caused by chemical reactions and by microbe activity or metabolism. Chemical decomposition is usually by oxidation, reduction, and hydrolysis. Microbe activity is affected by climatic and edaphic factors, such as high soil moisture content, temperature, and organic matter. Bacteria, fungi, and actinomycetes are the main groups of organisms that degrade pesticides.

Pesticides are used because they are toxic to specific weeds or insects, but they may also adversely affect nontarget organisms. A compound that inhibits nitrifying bacteria may cause a reduction in the rate of nitrate formation. A chemical increasing or suppressing carbon mineralization may also increase or decrease destruction of native organic matter or plant residues. A pesticide harmful to rhizobium may be undesirable because it can prevent root nodule symbiosis. Hence, a pesticide should be investigated to determine if it is detrimental to any segment of the soil community necessary for soil fertility, crop development, or pest-free plants.

Persistence of pesticides in soils concerns (a) the time span a pesticide remains effective, (b) danger of carryover to succeeding crops, and (c) adverse residue accumulations in other segments of the ecosystem. Factors influencing persistence include the pesticide itself; kind of soil; soil moisture status; temperature; application rate, depth of placement, and formulation of the pesticide; soil pH; and microbial activity.

Since many factors and processes are involved in the degradation and persistence of a pesticide, it is impossible to give the exact length of persistence for a particular pesticide. Table 14-1 shows the

approximate length of active life of some corn and soybean herbicides at commonly applied rates.

3. PROBLEMS OF SOIL, WATER, AND PLANT MANAGEMENT AND PESTICIDES

EROSION AND PESTICIDES

Soil particles adsorb pesticide ions on their surface. Some of the most commonly used pesticides have limited downward movement in the soil. As a result of these factors, controlling erosion by conservation measures is significant in preventing pesticide pollution.

Results from a severe storm in July 1969 on the North Applachian Experimental Watershed, Coshocton, Ohio, illustrate the effective use of soil conservation in pollution abatement.

Cornland without conservation farming lost 22 tons of soil per acre. With conservation farming 3 tons of soil per acre was lost; with no-till corn culture the soil loss was 0.03 ton per acre. Thus, transport of dieldrin was greatest on land without conservation farming. There was 80 percent less on land with conservation farming and almost zero transport on the no-till land.

Water runoff after application of chemicals is of particular concern. Tests show that quantity of chemical pollutants removed from cropland by water is related to size of storm, intensity of rainfall, and length of time between application of chemical and rainfall.

Researchers of the South Piedmont Conservation Research Center report that in one test, 13 percent of 2,4-D (ester form), applied at a rate of 2.2 lb per acre, was lost in a 1-year frequency storm. In a 100-year-frequency storm the loss was 26 percent.

In another test atrazine was applied at the rate of 3 lb per acre before a simulated 2.5-inch storm. When applied 1 hour before the storm, 17 percent of the atrazine was lost in the runoff. When the chemical was applied 96 hours before the simulated storm, 7 percent of the atrazine was lost in the runoff.

Water erosion produces the most sediment, but wind erosion contributes almost 15 percent[2/] of the total sediment produced in this country per year. In areas where wind erosion is a problem, it is not uncommon to lose more than 20 tons of soil per acre per year. Wind erosion is a dominant problem on 55 million acres of cropland.

RELATIONSHIP OF CONSERVATION TILLAGE SYSTEMS AND PESTICIDES

Various conservation tillage systems have particular advantages in controlling erosion by both water and wind. Conservation tillage decreases the transport of dissolved pollutants and reduces the movement of eroded solids. Controlling erosion stops much of agricultural pollution.

But weeds, insects, crop diseases, and rodents may increase in conservation tillage, which often requires increases in pesticide use.

[2/] Woodruff, Neil. Wind Erosion Laboratory, Agr. Res. Serv., U.S. Dep. Agr. Personal communication. 1972.

Table 14-1.--Average persistence of pesticides in medium-textured soils under normal Illinois conditions[1/]

Pesticide: Trade name	Pesticide: Generic name[2/]	Rate (active ingredient)	Time of application[3/]	Persistence
		lb/acre		No. months
AAtrex	atrazine	1 to 4	PPI, PrE, PoE	2 to 8
Alanap	naptalam	2 to 8	PrE	1 to 1-1/2
Amiben	amiben	2 to 3	PrE	1-1/2 to 2
	amitrole	2 to 10	PoE	1/2 to 1
Balan	benefin	3/4 to 1-1/2	PPI	4 to 5
Banvel	dicamba	1/4 to 4	PrE, PoE	3 to 12
Bladex	cyanazine	1 to 4	PrE	2 to 3
Caparol	prometryne	1 to 3	PrE	2 to 4
Casoron	dichlobenil	2 to 6	PrE, PoE	2 to 6
Chloro IPC, Furloe	chlorpropham (CIPC)	2 to 8	PrE	1/2 to 1
Cobex	dinitramine	1/3 to 2/3	PPI	3 to 8
Dacthal	DCPA	6 to 10	PrE	2 to 3
Dowpon, Basfapon	dalapon	5 to 10	PoE	1/2 to 1
Dymid, Enide	diphenamid	4 to 6	PrE	3 to 6
	2,4-D	1/4 to 3	PrE, PoE	1
Eptam, Eradicane	EPTC	2 to 4	PPI	1-1/2 to 2
Hyvar-X	bromacil	4 to 20	PrE	2 to 18
Karmex	diuron	2 to 4	PrE	3 to 6
Knoxweed[4/]	EPTC + 2,4-D	...	PrE	1 to 2
Lasso	alachlor	2 to 4	PPI, PrE	1 to 2
Lorox	linuron	1/2 to 3	PrE, PoE	2 to 4
Maloran, Bromex	chlorbromuron	1 to 6	PrE, PoE	2 to 4
Outfox	cyprazine	3/4 to 1	PoE	2 to 6
Paraquat	paraquat	1/2 to 1	PoE	1
Planavin	nitralin	1/2 to 1-1/2	PPI, PrE	3 to 6
Pramitol	prometone	10 to 25	PrE	2 to 18
Preemerge	dinoseb (dinitro)	6 to 9	PrE, PoE	1
Prefar, Pre-San, Betasan	bensulide	4 to 6	PrE	1 to 2
Princep	simazine	1 to 4	PPI, PrE	2 to 8
Pyramin	pyrazon	2 to 4	PrE	1 to 2
Ramrod	propachlor	4 to 6	PrE	1 to 1-1/2
Sencor	metribuzin	1/8 to 1	PrE	1 to 4
Solo[4/]	maptalam + chloropropham	...	PrE	1 to 1-1/2
Sutan +	butylate	2 to 4	PPI	1-1/2 to 2
Tandex	karbutilate	3 to 25	PrE	2 to 18
Telvar	monuron	1 to 4	PrE	2 to 6
Tillam	pebulate	3 to 5	PPI	1-1/2 to 2
TOK	nitrofen	3 to 6	PoE	1 to 2
Tordon	picloram	1/4 to 2	PoE	2 to 18
Treflan	trifluralin	1/2 to 1	PPI	3 to 6
Vernam	vernolate	2 to 4	PPI, PrE	1 to 2

[1/] From McGlamery, M. D. and E. L. Knake. Persistence of herbicides in soil. U. Ill. Agronomy Facts W-22a (mineogr.) 1973.

[2/] Generic name is the coined name approved by Weed Society of America.

[3/] PPI is preplant incorporated; PrE, preemergence; PoE, postemergence.

[4/] A mixture; the most persistent ingredient is underlined.

Crop residues, essential to the success of conservation tillage systems, may intercept pesticides and prevent them from reaching the soil where they are most effective. Rates of application of pesticides are increased at times to overcome this interception by crop residues. Land operators must use skill in applying pesticides where there are crop residues. In conventional tillage an error in herbicide application can be corrected by clean cultivation, but correction is not easy in conservation tillage systems.

Table 14-2 shows the results of conservation tillage in which 4 to 7 tons of mulch were applied on the surface.

Table 14-2.--Runoff from continuous no-till corn, 1965-1970, on Watershed No. 191, Coshocton, Ohio

Year	Runoff	Erosion
	Inches	Ton/acre
1965	0	0
1966	0	0
1967	0.0211	0
1968	0	0
1969	0.1850	0.006
1970	0	0

RELATIONSHIP OF CONVENTIONAL TILLAGE, FALL TILLAGE, AND PESTICIDES

Conventional tillage is using a moldboard plow followed by liberal use of a disk, harrow, hoe, or cultivator. The system often results in excessive tillage and formation of a soil crust that reduces the rate of water intake. The soil is subject to wind and water erosion, which in turn increase the risk of pesticide pollution.

Some agricultural authorities recommend practices that may increase both erosion and problems of pesticide use. Such recommendations are common and widespread. Fall tillage, such as plowing, disking, and chiseling, is an example. Occasionally fall tillage is justified, but the practice is often used on land that does not need it, thus making possible more pesticide contamination.

RELATIONSHIP OF MONOCULTURE AND PESTICIDES

Monoculture can contribute to pesticide hazards. Monoculture of corn, wheat, cotton, or rice in continuous blocks of many acres requires large amounts of pesticides. In the drive to increase production, the use of crop rotations has declined. Because of labor problems, large machinery, larger farm units, and specialization, many crop rotations, especially those including grasses and legumes, are no longer used. With crop rotations, traditionally used to control certain pests and diseases, pesticides were not needed so much as they are today. The

trend toward monoculture reaffirms the need for farmers to use pesticides with care.

4. POLLUTION ASPECTS OF NITROGEN, PHOSPHORUS, AND OTHER PLANT NUTRIENTS

NITROGEN

The use of nitrogen in agriculture has increased tremendously over the last few decades. Coincident with this increase has been a degradation of water quality in many places due to nutrient enrichment.

Nitrogen fertilizer added to cropland is only one of several sources from which nitrogen can escape to other ecosystems. Other sources are (a) natural inputs from rainfall, biological activity, and runoff and percolation from forests and natural grasslands; (b) runoff and percolation from cropland and pastures; and (c) man-generated sources such as domestic and industrial wastes and runoff from urban centers.

Nitrogen in nitrate form is not adsorbed to any extent on soil particles and is free to move with the soil water. Generally, the nitrates lag behind the water[3/] because most cultivated soils in the United States are below field capacity during the growing season. Rainwater carrying the nitrate ion moves first into the noncapillary pores and then is rapidly drawn into capillary pores. The nitrogen thus is pulled into pores where it is protected from leaching.

Nitrogen added at the start of the growing season is not likely to be leached out of the soil before crops have full opportunity to use it. But nitrogen added in the fall is subject to leaching losses in the humid parts of the United States. Excess water applied through irrigation carries nitrogen into ground water and streams. Leaching losses of nitrate occur when plants are not growing, that is, between harvest and the start of the growing season.

Most fertilizer nitrogen is taken up by plants. A large quantity that is unaccounted for is probably lost through denitrification as elemental gas with no pollution consequence. Nitrogen may become tied up in the microbial and organic fraction that is carried over to the next crop or lost, or it may be carried below the root zone to the water table. Therefore, the presence of nitrogen in a stream running through a heavily fertilized area does not necessarily mean that it came from applied nitrogen fertilizer.

Pollution from nitrogen fertilizer can be minimized by increasing the nitrogen fertilizer efficiency. Nitrogen efficiency can be improved by (a) reducing erosion; (b) proper placement, amount, and timing of nitrogen applications; (c) using slow-release forms of nitrogen; (d) using nitrification inhibitors; (e) planting cover crops and leaving crop residues; (f) proper water management under irrigation; and (g) applying conservation cropping systems. If crops are harvested and good conservation practices are followed, the nitrate loss from farming should be no greater than the amount lost from forests or grassland.

[3/] Paper given by Guy D. Smith at 1971 ARS-SCS Workshop on pollution, Oxford, Miss.

PHOSPHORUS

Phosphorus in fertilizer added to soil is rapidly immobilized through adsorption on clays or precipitation as calcium, iron, or aluminum phosphates.[4/] The formation of these compounds reduces the movement of phosphorus in the soil water by either mass flow or diffusion.

Some of the phosphate compounds are crystalline and with time disappear by dissolving or become less available by forming less soluble phosphates. The phosphate ion is adsorbed on fine soil particles and reaches streams and lakes attached to sediment. While the sediment is in suspension, the phosphorus is slowly available to aquatic plants. After the sediment settles in a lake, estuary, or reservoir, the phosphorus is unavailable except to plants rooted in the sediment. Erosion control practices together with use of fertilizers to help provide good plant cover can reduce rather than increase pollution from phosphorus.

Numerous sources contribute phosphorus to the environment. These sources include municipal runoff and sewage effluent, industrial discharges, individual sewage disposal systems, runoff and sediment from agricultural cropland and nonagricultural lands, domestic animal waste, and rainfall. Most of the evidence and data, however, suggest that phosphorus pollution from agriculture is minor in comparison to that from other sources.

POTASSIUM, CALCIUM, MAGNESIUM, AND SULFUR

There has been little concern about the increased use of potassium fertilizers because there are no indications that potassium enrichment of water promotes growth of algae.[4/] The effect of additions of calcium, magnesium, and sulfur to the chemical composition of water is neglible in comparison to the effect of soils and their parent materials on water quality.

TRACE ELEMENTS

Concentrations of trace elements in living tissues are ordinarily low. These concentrations, however, must often be maintained within narrow limits to permit desired performance by plants and animals.

Some typical concentrations and amounts of trace elements in different phases of their environmental cycles are shown in table 14-3.

[4/] Stanford, G., C. B. England, and A. W. Taylor, Fertilizer use and water quality. 19 p. Agr. Research Serv., U.S. Dep. Agr. ARS 41-168. 1970.

Table 14.3--Concentration of selected trace elements in various phases of the environment[1/]

Element	Concentration: In geochemical reserves[2/]	Concentration: In soils (total)[3/]	Concentration: In plants[3/]	Concentration: Critical level in animal diets
	ppm	ppm	ppm	ppm
Arsenic (As)...	a: 2 b: 1-3 c: 0.033	6 (0.1-40)	1 (0.1-5); not required.	Not required; certain compounds medicinal; As^3, highly toxic; As^5, moderately toxic.
Boron (B)......	a: 10 b: 20-100	10 (2-100)	Deficiency, 5-30; toxic at +75 (wide species difference).	Not required; low toxicity.
Beryllium (Be).	a: 3 b: 1-3 c: 0.0000006	6 (1-40)	0.1; not required; toxic.	Not required; highly toxic.
Bismuth (Bi)...	a: 0.17 b: 0.3-1 c: 0.000017	---	0.06; not required; toxic.	Not required; moderate toxicity.
Bromine (Br)...	a: 2.5 b: 1-6 c: 65	5 (1-10)	15; not required; low toxicity.	Not required; may antagonize Cl or I; Br^-, low toxicity Br_2, highly toxic.
Cadmium (Ca)...	a: 0.2 b: 0.03-3 c: 0.00011	0.06 (0.01-7)	(0.2-0.8); not required; toxic.	Not required; moderate to high toxicity.
Chromium (Cr)..	a: 100 b: 10-100 c: 0.00005	100 (5-3,000)	(0.2-1.0); not required; moderately toxic.	Required at ?; low toxicity.

Table 14.3--Concentration of selected trace elements in various phases of the environment[1]--Continued

Element	Concentration			
	In geochemical reserves[2]	In soils (total)[3]	In plants[3]	Critical level in animal diets
	ppm	ppm	ppm	ppm
Cobalt (Co)....	a: 25 b: 1-20 c: 0.00027	8 (1-40)	(0.05-0.5); required at < 0.02 by legumes.	Required at 0.07 by ruminants; low toxicity.
Copper (Cu)....	a: 55 b: 5-45 c: 0.003	20 (2-100)	Required at 2-4; normal 4-15; toxic at +20.	Required at 1-10, depending on Mo; low toxicity.
Fluorine (F)...	a: 625 b: 250-750 c: 1.3	200 (30-300)	Not required; normal 2-20; toxic at +50.	Not required; beneficial to bones and teeth; moderate toxicity.
Iodine (I).....	a: 0.5 b: 1-2 c: 0.06	5	Not required; normal 0.4; toxic at 10-20.	Required at 0.1-1; low toxicity.
Lead (Pb)......	a: 12.5 b: 5-20 c: 0.00003	10 (2-200)	Not required; normal 0.1-10; toxic in culture solution.	Not required; moderate toxicity.
Manganese (Mn).	a: 1,000 b: 50-1,100 c: 0.002	850 (100-4,000)	Required; normal 15-100; toxicity depends on Fe-Mn ratio.	Required at 10-40.
Molybdenum (Mo)	a: 1.5 b: 0.2-3 c: 0.01	2 (0.2-5)	Required at <0.1; normal 1-100; low toxicity.	Required at <0.1; moderate to high toxicity, dependent on Cu.

Table 14.3--Concentration of selected trace elements in various phases of the environment[1]--Continued

Element	Concentration: In geochemical reserves[2]	In soils (total)[3]	In plants[3]	Critical level in animal diets
	ppm	ppm	ppm	ppm
Nickel (Ni)....	a: 75 b: 2-70 c: 0.0054	40 (10-1,000)	Not required; normal 1; toxic at +50.	Not required; moderate to low toxicity.
Selenium (Se)..	a: 0.05 b: 0.1-1.0 c: 0.00009	0.5 (0.1-2.0)	Not required; normal 0.02-2.0; higher in accumulators; toxic at 50-100.	Required at 0.05-0.20; highly toxic.
Strontium (Sr).	a: 375 b: 20-700 c: 8.1	300 (50-1,000)	Not required; normal 5-3,000; non-toxic.	Not required; beneficial to teeth and bones; ^{90}Sr hazard.
Vanadium (V)...	a: 135 b: 20-150 c: 0.002	100 (20-500)	Required by some algae; normal 0.1-10; toxic at +10.	Not required; may be beneficial; moderate toxicity.
Zinc (Zn)......	a: 70 b: 10-100	50 (10-300)	Required at 8-15; toxic at +200.	Required at 10-40; low toxicity.

[1] From Allaway, W. H. Trace element cycling. In Adv. Agron. 20: 235-274. Academic Press, N.Y. 1968.

[2] Values indicated: a, for igneous rocks; b, sedimentary rocks; c, seawater.

[3] First value is typical concentration; value in parentheses is range.

A number of different practices help in agronomic control of trace element problems. These are (a) soil selection, (b) trace element fertilization, (c) soil management to increase or decrease the availability of trace elements in the soil, (d) crop selection, and (e) crop management and utilization.

Concentration of trace elements in a specific plant varies, depending mostly on soil characteristics. Soils are often selected to avoid heavy concentrations of trace elements; for example, in the West soils are selected to avoid excessive concentrations of molybdenum in forage crops.

The most direct method of increasing the concentration of a trace element is to apply it to the soil or to a plant. Direct application increases crop production. The concentration of a trace element can be controlled by using the proper quantity and technique for application.

Soil management practices can control trace element problems. Changing the soil reaction by applying lime affects the solubility of trace elements by favoring changes in their oxidation state. Heavy application of phosphorus fertilizers reduces the availability of some trace elements. Drainage, leaching, and the addition of organic matter can reduce detrimental concentrations.

Different plant species growing on the same soil contain different concentrations of different trace elements because some plant species accumulate only certain trace elements. Varietal differences relative to accumulation of trace elements are also evident. Crop selection is effective in controlling trace elements in plants and in avoiding deficiencies or excesses in plants or animals.

Ryegrass accumulates iodine. Differences in the ability of two strains of soybeans to accumulate iron and to grow on soil low in available iron have been reported.[5/] Grass pastures instead of legumes or legume-grass mixtures can reduce molybdenum toxicity on some soils.[6/] On soils where available cobalt is marginal, legumes may contain enough cobalt for ruminant animals but grasses generally do not.[7/]

Crop management to control the movement of trace elements from plants to animals is based on changes in trace element concentrations in crops at different stages of growth, differential concentrations in different parts of plants, or differences in the availability to animals of trace elements as plants mature or are processed for animal consumption.

5. PESTICIDE WASTE DISPOSAL

A variety of resource information is available on the safe disposal of pesticide waste materials. This discussion is not comprehensive; it considers relatively small quantities of pesticide wastes and the responsibilities of the farmer, grower, homeowner, and others. Other SCS guidelines for waste disposal are enumerated in appropriate SCS policy statements and memoranda.

[5/] Brown, J. C. Iron chlorosis in plants. Adv. Agron 13:329-69. Academic Press, N.Y. 1961

[6/] Kubota, J., et al. Relationship of soils to molybdenum toxicity in grazing animals in Oregon. Proc. Soil Sci. Soc. Amer. 31:667-71. 1967.

[7/] Kubota, J. Cobalt content of New England soils in relation to cobalt levels in forages for ruminant animals. Proc. Soil Sci. Soc. Amer. 28:246-51. 1964.

These pesticide wastes include:

a. Spills resulting from leaks or careless handling
b. Empty pesticide containers
c. Surplus spray mixtures

Proper disposal of wastes must be as much a part of the total pesticide control program as the transportation, marketing, and use of pesticides. Selecting a disposal area is one of the first steps for proper disposal. For a suitable disposal area:

a. The ground should be relatively high, flat or gently sloping away from any surface or subsurface water supply, or 50 to 100 feet downslope from any water supply facility such as a well or pond.
b. The soil should be 8 to 10 feet deep from surface to bedrock or hardpan if there is lateral movement of subsurface water.
c. The area should not be used for any other purpose.
d. There should be easy access for all disposal needs.

Most labels on pesticide containers have instructions for disposal of pesticide wastes and the so-called empty containers. The instructions are important parts of the label and should be read, understood, and followed.

Spills of the packaged product before it is diluted for use can be either dry or liquid. Dry spills should be cleaned up immediately, placed in metal containers with tight lids, identified by intended use, and used for this purpose only. Scrub the contaminated area with plenty of water plus liquid detergent and caustic soda (lye). Then rinse area with clean water. Keep runoff from reaching water supply sources.

Liquid spills should be covered with absorbent material such as clay, hydrated lime, sawdust, sweeping compound, or rags. Place contaminated absorbent material in suitable container and scrub the contaminated area as for dry spills.

In this discussion empty used containers are containers that are unfit for reuse and unsalvageable. Combustible containers that can be burned consist of paper, cardboard, cloth, other plant fiber, or certain plastics. Burn them in a waste disposal area downwind from residences, people, animals, and crops and other valuable plants. Not all combustible containers should be burned. Containers that have held products either highly volatile or highly toxic such as many of the herbicides and most of the organophosphate insecticides, containers of explosive materials such as chlorates, and aerosol containers should be buried in waste disposal areas.

Noncombustible containers consist of glass, certain plastic materials, and metal. Decontaminate them by pouring all excess pesticide in selected disposal areas. Rinse the containers with a suitable solution and pour rinse into the area. Table 14-4 gives generally accepted information on amount of materials to use for rinsing. After the rinse solution is in the container, close the container tightly, rotate occasionally, and allow at least 15 minutes of rinse exposure time. After rinsing, break glass containers, puncture plastic containers,

and bury the container and rinse in the same disposal area. Puncture holes in the top and bottom of metal containers except aerosol containers, and bury them with the rinse and other pesticide wastes.

Table 14-4.--Amount of rinse material[1/]

Container size	Water	Detergent	Caustic soda (lye)
Less than 5 gallons	1 pint	1 tablespoon	1 teaspoon
5 gallons	2 quarts	2 tablespoons	1/2 cup
15 gallons	1.5 gallons	1/4 cup	1/2 pound
30 gallons	3 gallons	1/2 cup	1 pound
55 gallons	5 gallons	1 cup	2 pounds

[1/] From Novak, R. G., and O. H. Hammer. Pesticide waste disposal. Down to Earth 26(2), Dow Chemical Company, Midland, Mich. 1970.

Disposal of aerosol containers is a special problem because of the risk of explosion if they are exposed to high temperatures or are punctured. Wrap empty containers in several layers of paper and send to a commercial incinerator or to a public sanitary landfill.

Surplus spray mixtures should be disposed of in waste disposal areas. Never allow surplus to get into irrigation, drainage, or water supply systems.

All pesticide wastes and empty pesticide containers should be covered with at least 18 inches of soil immediately after they are placed in a waste disposal area.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 15. WASTE MANAGEMENT EQUIPMENT

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CHAPTER 15. WASTE MANAGEMENT EQUIPMENT

1. GENERAL

This chapter describes equipment used for the collection, movement, treatment, and disposal of wastes. The equipment must be designed both to meet the requirements for pollution control and to handle the waste with reasonable cost and labor. Undersize equipment may prevent the waste management system from operating satisfactorily, resulting in improper handling of waste and subsequent pollution. Total operation and maintenance time and cost should be considered for various kinds of equipment to determine the most desirable systems.

The equipment must also be designed to handle wastes of the characteristics produced by a particular enterprise. The physical, chemical, and biological characteristics of waste material are discussed in chapter 4. Equipment is generally designed to handle wastes physically classified and described as follows:

1. Solids. The moisture content of the waste is such that there is no danger of leakage. The waste may be in small to large particles and can be handled with buckets or forks. The waste stacks easily and forms a mound.
2. Semiliquid or slurry. The waste is moist; it cannot be contained with forks, and it does not stack. It may be too thick to pump and handle in small irrigation systems.
3. Liquid. The waste is easily pumped and handled in pipelines. The moisture content is usually more than 95 percent.

Some wastes are not readily classified in any one of these categories. Waste water that carries hard material, such as seeds, stones, or chips, may have to be processed in several stages for final disposal. A change in the type of feed consumed by livestock may change the physical characteristics of waste and cause problems in operating the equipment.

Weather in some areas necessitates operational changes. Special equipment or system design may be needed for winter operations since some conventional equipment does not function during freezing weather.

In selecting equipment the following should be kept in mind:

1. Season and time available for waste disposal
2. Maintenance requirements of equipment
3. Availability of labor for handling equipment
4. Safety features

2. PUMPS

Pumping provides rapid loading, unloading, and transporting of liquid wastes. Pumps or similar equipment can also be used to agitate or aerate liquid wastes.

The operating and waste handling characteristics of different pumps need to be considered. A manufacturer is usually requested to provide a pump based on the specific requirements of a waste management system.

PUMP SELECTION

The pump should be compatible with the rest of the waste management system and farming operation. The different factors to be considered in selecting a pump follow.

Total Solids

Waste material must be in a slurry or liquid state for pumping. Swine and poultry manure can have more solids than cattle manure and still be pumped. Large pumps normally handle a greater percentage of solids than small ones. The performance of a pump depends on characteristics of the inflow to the suction pipe of the pump. Following are the approximate upper limits of performance (approximate maximum amount of total solids handled) of various pumps:

Type of pump	Cattle manure	Swine and poultry manure
	Percent	Percent
Diaphragm	15	20
Gear	Very high	Very high
Helical	15	20
Irrigation, centrifugal	7	12
Piston	20	30
Propeller	8	15
Trash, centrifugal	8	15
Vacuum	15	20

Size of Solids

Pumps are designed to handle various sizes of solids, usually 1 to 3 inches, depending on type and size of the pump.

Large centrifugal irrigation pumps are used for solids about 3/4 inch in diameter. Centrifugal trash pumps are used for solids up to 3 inches in diameter.

Some pumps have traps for easy cleaning when they become clogged with solids. Screens around suction hoses or inlets should pass the largest solids that the pump will pass. Auxiliary chopper blades at inlets or the impeller help reduce solids to a size that the pump can handle.

Since agitation is used to reduce solids in size and to mix the slurry, the system of agitation should be compatible with the pump selected.

Pressure Developed

Irrigation pumps normally provide adequate pressure for irrigation. The large big-gun sprinklers usually operate at pressures from 60 to 130 lb/in^2. Some centrifugal trash pumps may develop adequate pressure for irrigation, but efficiency is much lower than in regular irrigation pumps.

The operating requirements supplied to the manufacturer should consider both the suction and discharge sides of the pump. These include:

1. Static suction head
2. Friction head loss in pipelines
3. Head losses in connection, elbows, and other accessories
4. Velocity head loss at discharge and pressure head loss at sprinklers

The maximum and minimum operating heads or pressures should be determined. Pressure or velocity is also important for agitation of pits or ponds and circulation of oxidation ditches. Pump capacity curves are provided by manufacturers for oxidation ditch rotors or propellers.

Pump Capacity

The required capacity of pumps for disposal of wastes by irrigation should be considered in the basic design of the management system, with emphasis given to quantity of wastes to be handled, application rates, and other factors, including time available for handling and disposal. Section 15, Irrigation, of the National Engineering Handbook provides methods for design. The Engineering Field Manual and state irrigation guides also provide useful information.

Charts and curves for calculating the time required for disposal or handling of waste materials are given in chapter 11 of this manual.

Character of Waste Materials

Since some waste materials may be highly corrosive, pumps must be selected and managed to resist corrosion. Removing the pumps from the liquid slurry and rinsing them with clean water is a good practice. Pumps or other equipment located in the head space of tanks are usually more subject to corrosion from gases in the tanks than immersed equipment. The best practice for resisting corrosion is to have the pump and accessories out of the manure or head space.

Herbaceous material, poultry feathers, and animal hair, especially from swine, clog pumps. Added choppers or strainers provide some protection from these materials. Hard solids such as feed, stones, or similar material can cause severe wear to the pump. These hard materials do not stay in suspension and usually are not picked up in pumping.

PUMPS IN GENERAL USE

Typical pumps and characteristics of some pumps in general use are shown in table 15-1. Actual manufacturers' data should be referred to when considering a pump for a waste management system.

Table 15-1.--Characteristics of typical pumps
[Absence of entry indicates entry not applicable or information not available]

Pump	Size	Brake horsepower	Revolutions per minute	Head	Capacity	Solids size
	in	bhp	r/min	ft	gal/min	in
Diaphragm	2 x 2	1.5	1,725	25	20	1-1/2
	4 x 4	7.0	3,600	30	104	2-1/4
Gear	3	16.2	400	230	200	---
Helical		10	390	65	85	---
		30	540	260	110	---
Irrigation-centrifugal.	2-1/2 x 2-1/2	5	3,000	130	110	---
	6 x 6	100	1,750	230	1,300	3/4
Piston	9 to 12	7.5 to 10	---	Small, 10 to 15	---	3
Propeller	3-1/2	5	1,750	19	100	---
	4	30	3,600	95	300	2
Trash-centrifugal.	3 x 3	14.5	3,200	75	375	2-1/2
	6 x 6	55	2,400	85	1,000	3
Vacuum	4 to 6	Tractor	500 to 1,000	23 to 35	250 to 350	3

Diaphragm

Diaphragm pumps are not in general use. They are used mostly to transfer liquid waste from tanks, pits, or lagoons to other facilities.

Gear

These pumps operate under severe conditions of viscosity, high solids content, or abrasive material and are now used in manufacturing and mining industries.

Helical

Helical pumps are especially designed to handle slurries. These pumps develop unusually high heads. The operating horsepower is directly proportional to the length of the helical.

Irrigation-Centrifugal

A centrifugal irrigation pump should be used to obtain the high heads needed for operating a big-gun sprinkler. Solids must be broken up (3/4 inch or less) for proper operation.

Piston

Piston pumps are commonly used to push manure from a pit in the barn to a holding pond or lagoon. Piston pumps operate under manure and usually deliver liquids and solids to the bottom of the lagoon.

Propeller

Centrifugal propeller pumps with auxiliary blades that break up the solids before they enter the driving propeller are especially useful for agitation and transfer of wastes to tank wagons. They are considered low-head, high-capacity pumps.

Trash-Centrifugal

This pump is built to handle solids and for easy cleanout when clogged.

Vacuum

Vacuum pumps are used on tank wagons to create a vacuum for filling the wagon or pressure for discharging the waste from the wagon. Since the pump does not operate in the liquid waste, it does not have to be protected against corrosion. The suction hose is 4 to 6 inches in diameter and can suck slurries containing as much as 20 percent solids. The hose may be pulled against the tank or pit floor, which prevents loading. Hay and straw longer than 4 inches may clog the suction hose.

3. AGITATION

Liquid waste stored in pits or ponds tends to separate into solid and liquid forms. The solids in the liquid may float or settle, depending on their character. Agitation breaks up the solids and brings them into suspension, preventing too much solids buildup and preparing the slurry for pumping or transfer. Proper consistency of slurry, about that of cake batter, keeps solids in suspension. Too much water causes separation, and suspension does not last. Regular agitation at the right moisture content prevents formation of crusts and layers. Good agitation for pumping lasts about 1 day.

Agitation is done mostly by pumps, but augers, diffusers, and paddle- or propeller-type equipment may be useful. Effective agitating equipment can reach about 30 ft. Baffles in tanks may facilitate agitation.

Some solids such as long straw, twine, and wire can cause problems with equipment. Screens should be provided to prevent these materials from entering the storage facility.

Safety precautions are necessary in all phases of agitation. Tanks inside buildings should be fully ventilated before and during agitation. A tank should never be entered unless it is properly ventilated to exhaust the gas. A lifeline should be used and a guard posted. Scuba gear should be used in dangerous areas.

Vigorous agitation can break the seal on earth ponds, causing seepage. A concrete floor at the pump intake will prevent erosion of soil at this location.

4. MANURE SPREADERS

Manure spreaders are generally in one of the following categories:

1. Closed-tank wagons, circular tanks mounted on wheels, used mostly for handling liquid manure and other moist waste materials
2. Wagon-type spreaders, boxes mounted on wheels such as an open-bed wagon, used mostly for spreading manure with bedding
3. Open-tank type wagons, used mostly for spreading both liquid and solids that can be spread by flail chains

CLOSED TANK WAGONS

Tanks on wheels with attachments, including pumps, agitating augers, and soil injectors, are used to transfer slurries to soil disposal areas. The tank wagon shown in figure 15-1 is in position for loading from a concrete holding tank. Most wagons are pulled and operated by farm tractors; however, truck-mounted wagons are common, especially for large enterprises and for handling sewage sludge and septic tank waste.

Capacity

Wagons range in capacity from 500 to 3,150 gal. Capacity is measured to the nearest gallon for a closed tank, not counting inside structural members (American Society of Agricultural Engineers [ASAE] Standard S326).

The large tanks weigh as much as 3 tons empty and as much as 15 tons loaded. Load limits on highway and field areas must be considered in planning waste management systems that use heavyweight tanks. If the soils are wet, the large tanks may get stuck and it may be necessary to dump the waste. Large tanks are usually provided with brakes. Surge control during starting and stopping for closed tanks should meet criteria in ASAE Recommendation R207.8.

Loading

The tank can be filled by using a separate tractor-operated impeller manure pump that is also used for agitating the slurry. Other types of pumps, conveyor systems, or gravity feed can be used for filling.

Vacuum pumps are built into many of the tanks. They are usually the vane type operated by the power takeoff (PTO) of the tractor. These pumps are installed so that they do not operate within the liquid slurry. They are less expensive than most pumps, relatively trouble free, and corrosion resistant. Pumps are geared to operate at 500 to 1,000 revolutions per minute (r/min).

The minimum loading vacuum is about 1 inch mercury per foot of lift. Most vacuum pumps are direct drive and move about 135 ft^3/min of air at 85 to 90 percent vacuum for filling. The tanks fill in 2 to 10 minutes. The suction hose ranges from 4 to 6 inches in diameter and handles slurries that have a little more than 80 percent moisture. The hose usually does not handle cobs, hay, or straw longer than 4 inches. It may be sucked against the pit floor, preventing loading.

Figure 15-1.--A closed-tank wagon (courtesy Clay Equipment Corporation).

Agitation

Augers and air jets are the most common means of keeping the slurry in the tank from separating during transport. Tank wagons are also used to agitate waste material in holding tanks and pits. Special reducers, usually a 1-inch flexible hose attached to a 10-ft section of metal pipe used as a probe, are attached to the intake. Several of these reducers can be attached to one intake. Agitation by tank wagon blowback is not very successful for cattle manure, which forms a hard crust.

Unloading

Tank wagons are unloaded by air pressure, an auger, or a gravity feed system. The usual unloading air pressure is about 3 to 5 lb/in^2 The maximum safe tank pressure is about 15 lb/in^2.

Unloading is usually completed in 2 to 6 minutes. The rate of unloading is controlled by the pressure or the PTO speed of the tractor.

The slurry can be injected or plowed into the ground or spread as a swath 20 to 45 ft wide. A tankful of slurry can cover 1/3 to 3/4 acre.

Maintenance is required on tank wagons. Flushing may be needed to control odor, sediment must be removed, and vacuum pumps require flushing. Proper greasing is also essential.

WAGON-TYPE

The wagon-type spreaders are used for manure in the solid state. This manure usually has bedding material added. It can usually be handled by fork loaders. Moisture leakage is uncommon.

Capacity

Capacity can be rated in tons, bushels, or cubic feet. ASAE Standard S324 recommends that the volumetric capacity of box-type manure spreaders be reported in cubic feet. Capacity is determined and reported by two methods. The heaped-load capacity is measured with the manure stacked to 15 inches above the upper beater. The struck-level capacity is measured to the top of the sides or flareboards. Wagons have a capacity of 80 to 350 ft^3.

Loading

Solid manure can be loaded onto wagons in various ways. Tractor or self-propelled loaders, conveyors and elevators, or push and gravity systems are used. Loading is usually rapid, depending mainly on size of the loading equipment.

Unloading

Wagons have unloading apron chains and bars that deliver the manure to beaters at the rear of the wagon. The aprons can be variable in speed, and the rate of application can be varied by changing tractor speed.

Boxes are tapered to be wider at the rear than at the front to reduce friction and to aid in unloading. One to three beaters operate at about 300 r/min to separate, break up, and scatter manure in a uniform pattern on the ground. A lower beater handles fine materials, and an upper beater handles heavy straw.

Since heaped capacity is measured to 15 inches above the top of the highest beater, a wagon with an upper beater may have larger capacity than the same wagon with a single beater.

Most equipment has a hydraulic endgate or can have one added. The endgate (fig. 15-2) holds soupy manure without spillage.

Figure 15-2.--A wagon-type manure spreader with endgate (courtesy Gehl Company).

OPEN-TANK TYPE WAGONS

If manure is semiliquid and soupy, there may be too much leakage from a wagon-type spreader and an open-tank type spreader (fig. 15-3) must be used. A self-loading wagon, commercially available, is good for use on paved lots.

Capacity

ASAE standard S325 recommends volumetric capacity determinations for open-tank type spreaders. The struck-level capacity is measured to the top of the sideboards or the fluid-holding level in the tank. The heaped capacity includes the full volume of the open tank and the hood. Capacity is given in cubic feet.

Tanks now available range in size from 100 to 400 ft^3 struck-level capacity.

Figure 15-3.--Open tank-type spreader (courtesy Sperry-New Holland Company).

Loading

Loading can be by pumps, tractors, self-propelled loaders with buckets or forks, conveyors and elevators, or push and gravity systems. Since these wagons can handle both liquid and solid manure, they have a wide range of uses.

Unloading

The tank can be unloaded from either the right or the left side. Unloading is done by 20 to 40 flail chains, the speed of which may be 300 to 1,000 r/min. The slurry is spread a distance of about 20 ft to the side of the tank.

5. LOADERS AND BLADES

Waste-handling equipment,includes various buckets and blades, tractor mounted or self propelled. Care in selection is important as this type of equipment is also useful for other farm chores.

LOADERS

Tractor equipment can be front or rear mounted. Figure 15-4 shows a typical method of handling manure with a loader. The bucket attachment

Figure 15-4.--A manure loader (courtesy International Harvester Company).

comes in numerous shapes and sizes and can lift 1 to 2 tons at a time. Buckets can be as much as 96 inches or more wide. They can be mounted with forks to handle mostly solid materials or they can be solid for use with loose materials and slurries.

Self-propelled loading equipment (fig. 15-5) is also available. Self-propelled loaders are especially suited to small areas because of the tight turns they can make and because of the small overall size of the driving mechanism.

BLADES

Bucket loaders act as blades for many waste-handling jobs, but actual blades may be more useful for mounding manure in open feedlots and scraping open-stall housing and concrete floors.

Blades are available in different sizes. They can be rotated to the right or left as necessary to direct the waste. Some blades have wings attached to prevent material from rolling around the edge.

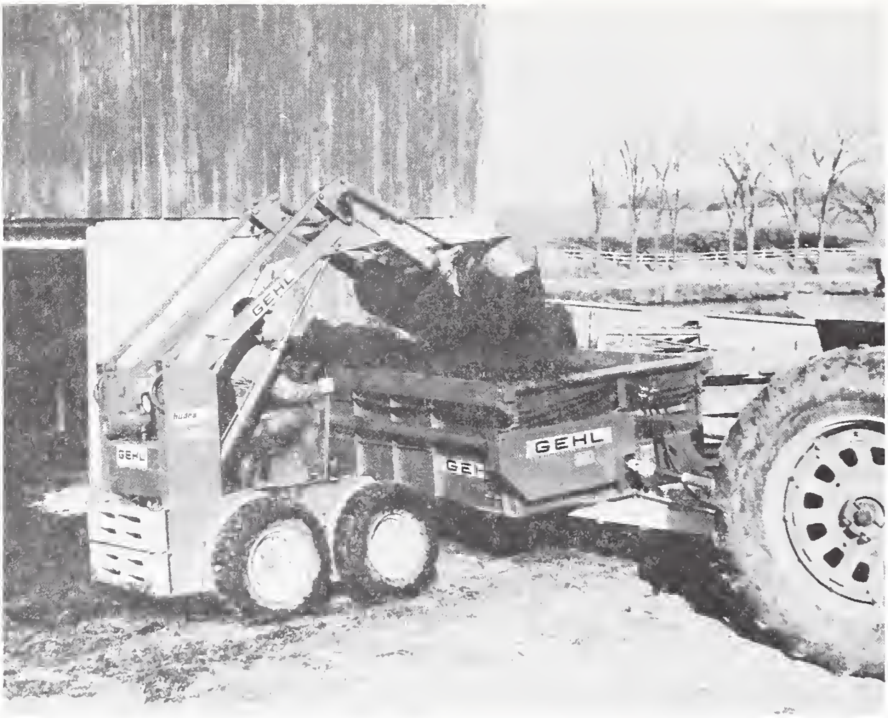

Figure 15-5.--A self-propelled manure loader
(courtesy Gehl Company).

6. CLEANERS

Mechanical cleaners are flanges of metal or other material that are pulled along a floor or in a gutter to carry wastes to a stacker or to other equipment that further conveys it to storage or to a wagon. Cleaners are especially useful in dairy barns with stalls. The variety of equipment is great. Designs are usually prepared only by company engineers or manufacturers' representatives. There are two general types of cleaners.

GUTTER CLEANERS

These cleaners move the animal waste along gutters in barns and are usually operated by hand switches. A typical gutter cleaner is pulled by a chain or cable and moves about 140 ft/min, cleaning about 15 ft of gutter in each cycle. The equipment is operated by a 1- to 1-1/2-hp motor. The cleaner can make 90° turns as shown in figure 15-6.

FREE-STALL BARN CLEANER

A typical free-stall barn cleaner is an iron paddle the width of a full alley that moves by chain continuously at about 5 ft/min to carry waste down one or more alleys to a gutter or pit at the end of the run. The cleaner is put into operation by a time switch and reverses automatically. Usually a 1- to 2-hp motor is required.

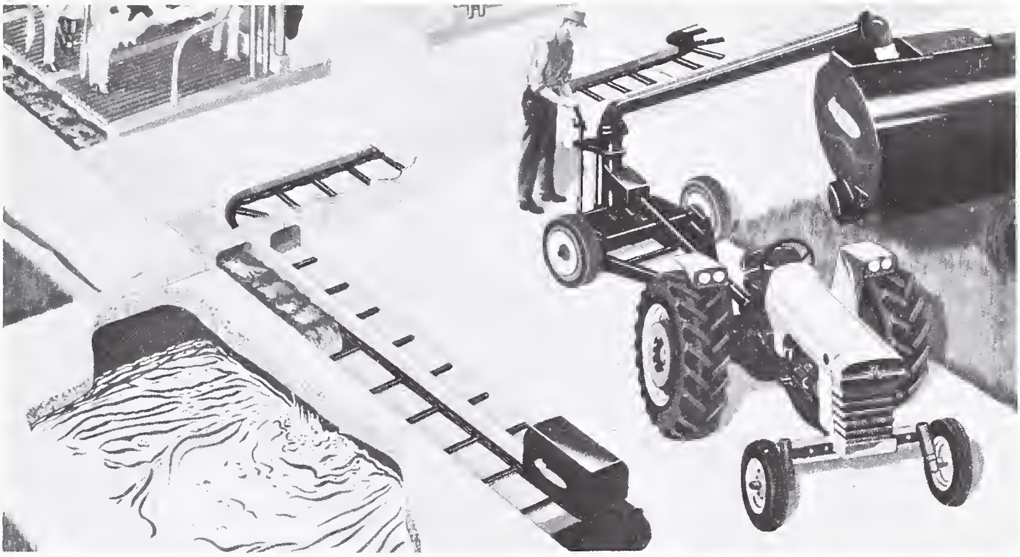

Figure 15-6.--Gutter cleaner
(courtesy Badger Northland Incorporated).

Barn cleaners can be used in single- or multiple-alley free-stall housing. They can also be used to scrape wastes from shallow pits under slatted floors into holding tanks or for delivery to stacking or loading facilities.

7. CONVEYORS - STACKERS - CARRIERS

Stackers and conveyors, similar to gutter cleaners and barn cleaners, are useful for handling large quantities of waste with minimum labor. Stackers or conveyors are usually used as an extension of the cleaners.

The paddles, conveyors, and the whole system must be designed to handle the particular waste produced. Design must consider moisture content and size and shape of the solid material.

CONVEYORS

Conveyors lift or deliver waste material directly to wagons for disposal or to storage areas. They operate in a concrete or metal gutter and have features similar to those of gutter cleaners.

STACKERS

Stacks are usually for temporary storage of waste material. Stacking equipment (fig. 15-7) is used primarily for manure with bedding such as that from many dairy operations.

Stackers for animal waste are 25 to 50 ft long and about 60 ft high. The vertical elevation can be about 55°, and the horizontal swing can be from 90° to any desired swing.

Figure 15-7.--A stacker
(courtesy Patz Company).

Cleaning paddles travel 20 to 150 ft/min and are operated by a 1- to 3-hp motor. Blowers also are used for stacking manure.

CARRIERS

Waste carriers are buckets that travel on a tramway. They are used mostly in barns for loading manure, which is then delivered to a stacking or loading area.

8. SOIL INJECTORS

Injecting waste into the soil reduces odor, nutrient losses by volatilization, and the risk of pollution by runoff from the disposal area. Injection equipment (fig. 15-8) usually consists of a closed-tank wagon with plow-down equipment or sweeps attached to the wagon.

The amount of waste disposed per acre depends on the pressure or gravity-feed method used and the speed of the equipment. Tank pressures usually range from 3 to 5 lb/in^2 and tractor speeds are about 3 miles per hour (mi/hr). If the manure bubbles out of the ground during injection, the tractor speed should be increased or the injection rate reduced. Usually about 1 gal of manure per foot is injected, but the rate in tons per acre or total nitrogen applied should be evaluated.

Sweeps are usually run at a depth of 6 to 10 inches. Sweeps unload 400 to 700 gal/min.

Some plow-down methods of waste injection are used. A furrow is plowed 6 to 8 inches deep, and the slurry is spread 1 to 2 inches thick in the furrow and covered.

Since the slurry injected usually has a high moisture content, it flows under force of gravity and the furrows and equipment should follow a contour line closely. Otherwise, liquid placed in a furrow on a slope will flow out of the ground.

Figure 15-8.--Soil injection equipment
(courtesy Sahlstrom Manufacturing Company).

Equipment properly designed for the soil and cover conditions should be used. Some sweeps do not operate in a heavy sod. Injection equipment has limited use in stony soils. Equipment is also usually limited to fields where row crops are no more than 15 to 20 inches high.

9. AERATION EQUIPMENT

Aerobic action requires an adequate supply of oxygen. Oxygen can be supplied by surface transfer in large ponds and by aeration equipment in tanks or small ponds where the surface area is too small for natural transfer.

Aerators can be used to reduce BOD and to control odor. Aerators are also used to condition liquids for recycling through flushing systems.

Aeration can be part of a tertiary treatment process for some waste material. Aerators have been used to treat domestic waste for a long time. They are receiving limited use in treating animal wastes.

Aeration equipment, usually operating 24 hours a day, has high energy requirements. Periods of operation are determined by the character of the waste, surface area and volume of the lagoon, and climatic conditions.

DIFFUSED AIR

Air is introduced into the waste material in fine bubbles through tubes laid in the tank. Air is pumped into the tubes and released through numerous holes into the waste water. Some tube systems are designed to rotate or keep the water in motion for better diffusion of air. Others have fixed air lines near the bottom and rely on the bubbles of air to mix the solution.

MECHANICAL AERATION

Propellers, rotors, paddles, and similar devices are used for aeration. The rate of oxygen transfer is determined by the kind of device, depth of submergence, temperature, size and shape of the tank, and character of the waste material.

Surface Aerators

Surface aerators for small lagoons are supported by polyurethane-filled floats. An electric motor supported by the float drives a propeller of an axial flow pump to mix air with the contents of the lagoon.

Rotors or Paddles

Rotors or paddles add oxygen by mixing air into liquid waste. Oxidation ditches are especially suited to rotors. Propellers are also used for circulating and injecting air into oxidation ditches.

10. SPRINKLERS

Sprinkler heads must be selected that will operate with the solids content and viscosity of the waste effluent. See chapter 12, part VII , for a discussion of spray application of liquid wastes.

MANURE SLURRIES

Big equipment is needed to handle manure slurries with a moisture content of 80 to 95 percent. Most of this equipment with a nozzle of at least 3/4-inch diameter can handle most domestic waste and animal or poultry waste without bedding or other hard material. Manure guns operate at pressures of 20 to 130 lb/in^2 with nozzles of 3/4- to 2-inch diameter. They deliver about 100 to 1,200 gal per minute with a diameter of 90 to 600 ft. Special equipment such as the travelling gun is designed to pull the sprinkler along unattended for about 1/4 mi. The rate of discharge from this big equipment may exceed the infiltration rate of many soils.

LIQUID MANURE

Waste materials with a solids content of 5 percent or less can be handled through regular smaller irrigation equipment or gated pipe.

Except for unusual liquid waste conditions, the smallest nozzle used should be about 3/16 inch. A screen on the intake is needed to keep solids such as straw, hay, or other hard material out of the equipment.

11. VENTILATION

Indoor waste storage facilities usually need ventilation for control of odor and poisonous or explosive gases. Such ventilation is also designed for climate control in housing areas.

These ventilating systems are usually designed for the flow of air to go down through the area, for example, slatted floors over tanks where waste accumulates in free-stall housing, and out over the surface of the waste. The fans for this ventilation are 12 to 36 inches in diameter and are operated by a 1/12- to 1/2-hp motor with a speed of 980 to 10,200 r/min.

The intake area is usually diffused and about 25 percent more than the exhaust area.

12. PIPELINES

Liquid can be transferred through pipelines. The pickup point can be at the source of wastes or a holding facility, with delivery made to a holding facility or disposal area.

DESIGN

Pipelines that work by gravity should not be less than 5 inches in diameter and should have a continuous grade to an outlet. Gravity pipelines should have full slug flow such as that provided by flushing. The inlet should be well rounded and protected to prevent entrance of solids that can plug the line. Velocity should be maintained at a minimum of 2.0 ft/sec. The inside of the line should be smooth to prevent sedimentation at joints and cracks.

Gravity lines should not be too long to unplug with a rod or plumber's friend. Openings for unplugging can be based on the rodding equipment on hand.

Pressure lines should be designed for full flow and to carry liquid at 5 to 6 ft/sec. Friction losses in pipelines can be assumed to be the same as for clear water. However, a 10-percent increase in horsepower is recommended because of solids and differences in viscosity of the waste fluids. Pressure should not exceed the allowable operating pressure of the pipe. Pressure relief, air release, vacuum relief, and drain valves should be used where applicable. Special valves designed to prevent clogging by solid particles should be used.

To prevent deposition of solids in the pipeline the velocity should be at least 1 ft/sec more than that at which the solids settle.

The deposition velocity can be calculated using the formula

$$V_d = F\sqrt{32.2D}$$

where V_d = deposition velocity in feet per second, F = Froude number for manure slurry (fig. 15-9), and D = inside diameter of the pipe.

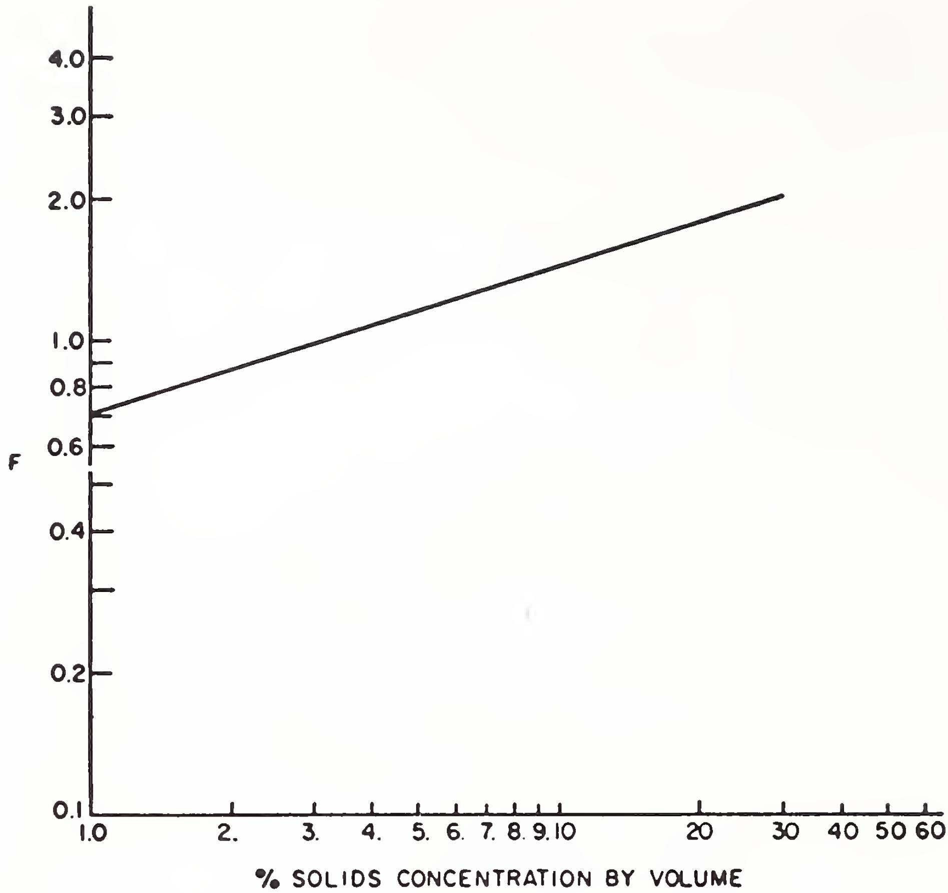

Figure 15-9.--Deposition factor for solids.

Underground lines should be designed to prevent plugging. Oversizing the line and using a minimum line of 6-inch diameter is helpful. Flushing the line with clear water after each use will prevent dry solid chunks from forming. If at all possible, a means of rodding the line at intervals of about 200 ft should be provided.

MATERIALS

Many liquid waste effluents are corrosive. Manufacturers should be asked for assurance that the pipe is resistant to corrosion from the wastes being handled. Metals, concrete, and some soft clay materials are subject to different types of corrosion. Flushing with clean water reduces corrosion. Precautions against galvanic corrosion should also be taken.

13. MISCELLANEOUS EQUIPMENT

Various kinds of specialized equipment for treating, sorting, transporting, and disposing of waste material are available. Canneries, cheese factories, slaughterhouses, and others use specialized equipment to process, sort, and recover or treat the end products.

Hydraulic manure-handling systems are especially useful for hog waste. They are also used for other livestock waste. A hydraulic system requires a high discharge pipeline or a storage tank to hold adequate water for periodic flushing. The flushing area can be the full floor or a gutter on the floor or under slats. Flushing can be operated by a timing device working a mechanical valve or a siphon.

CENTRIFUGE

A centrifuge is used in many canneries for separation of solids. The centrifuge is also being tested for separation of solid manure particles from liquids. A screen and auger combination, in which the auger moves the solids from the screen, may be of use where the cost can be justified.

COMPOSTING

Composting waste is a way of treating for disposal. Equipment for composting stirs, turns, and mixes the waste material. When the waste is stabilized, it can be spread on land without odor problems. Occasionally, it is bagged and sold for use in gardens and the like.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CHAPTER 16. MONITORING AND SAMPLING

Compiled by John P. Burt, sanitary engineer, SCS, Jackson, Miss.

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CHAPTER 16. MONITORING AND SAMPLING

1. GENERAL

Monitoring and sampling have been practiced for centuries. Early forms of monitoring probably were frequent observations of crops for success or failure. In their travels, the pioneers of this country sampled the soil and the surrounding wildlife and vegetation to determine whether an area was habitable. This checking of segments of the environment was a form of monitoring.

Today, various facets of the environment are being monitored to meet a particular need. These monitoring systems are concerned with basic resources, population, economy, health, and the like. They are complex systems and use an enormous amount of public funds, but they are essential to the well-being of the Nation.

This chapter discusses an approach to sampling and monitoring for two different purposes and is divided accordingly. The first part discusses sampling and monitoring of streams for evaluating surface water quality. The second part discusses monitoring and sampling of various animal waste treatment and disposal systems.

2. MONITORING AND SAMPLING TO DETERMINE SURFACE WATER QUALITY

Previous chapters of this manual define water-quality requirements for various uses of surface water and discuss sources of pollution and methods of waste treatment and disposal. This chapter discusses various methods of monitoring the water quality of streams and lakes. It provides guidance in collecting and analyzing water-quality data. Analytical results of water-quality surveys are helpful in describing some aspects of water quality, but such surveys do not provide a complete description of a water resource.

For evaluating water quality, monitoring and sampling are defined as follows:

1. Sampling is the physical act of collecting a volume of water for the sole purpose of analysis or analyses for various water-quality parameters.
2. Monitoring is frequent or routine systematic collection of samples over a period of time and analyzing them for an understanding of the variances in the water-quality parameters for a body of water. Monitoring as used in this section is not a continuous, unending process.

Analysis of a sample of water shows the water quality at a definite time at one sample collection station. To understand the fluctuation and variances expected in a body of water, a series of samples under varying circumstances is necessary.

MONITORING

Before an effective monitoring system can be initiated the following questions should be answered:

1. What is the monitoring objective?
2. What are the critical water-quality parameters for this monitoring objective?
3. What is the availability of water-quality data that relate to the project under investigation?
4. What visible factors in the drainage area influence water quality?
5. In what type of streams is the sampling to be conducted--ephemeral, intermittent, perennial?
6. What is the necessary frequency and duration of sampling?

1. What is the monitoring objective?

The objective of a monitoring system should be the first determination. The proposed use of the water determines which water-quality parameters are the most important to monitor.

Monitoring water quality in the past has been mostly for multi-purpose reservoirs that store water for contact sports or public raw-water supply, or both. Comments in response to environmental impact statements now suggest that water-quality analyses should also be conducted on projects related to altering or regulating waterflow. Reviewers of impact statements are concerned about the changes in a stream's water quality, e.g., in temperature, dissolved oxygen, re-aeration rate, suspended solids, turbidity, and the like, that may occur after a watershed project is completed. The purpose of water-quality monitoring therefore governs many of the decisions that should be made before establishing a monitoring system.

2. What are the critical water-quality parameters for this monitoring objective?

a. Recreation use - water contact sports

The crucial water-quality parameter for water contact sports usually is the fecal coliform bacteria count. Because a participant can ingest water during swimming or water skiing, the allowable bacteria count in lakes and streams used for contact sports usually is limited to 200 fecal coliform/100 ml as a maximum monthly geometric mean. No more than 10 percent of the samples shall exceed 400 fecal coliform/100 ml. Fecal streptococci are also frequently analyzed to determine the source of fecal material.

The chemical and physical quality of water may be a critical factor in the use of water for sports in certain regions of the country. While local water-quality experts may be able to estimate chemical and physical qualities of water, enough analyses should be made to verify these estimates.

b. Public raw-water supply

As in water for recreation, the bacterial limit is a crucial parameter for a public raw-water supply. But raw water for public use is usually allowed a higher concentration of fecal coliform bacteria than recreation water since all surface water has some treatment and disinfection before it is distributed to consumers. The source of the fecal coliform bacteria is important in determining the suitability of a water supply for public use.

The chemical and physical analyses of water for public use are as critical as the bacterial analysis. The list of allowable concentrations of various constituents is lengthy, but the water should be analyzed for each constituent if there is any question about existing concentration. The analysis is necessary to prepare designs and estimate costs for water treatment plants and to determine possible hazards to consumers' health.

c. Agricultural water use

The parameters for monitoring and sampling water for agriculture depends on the intended use of the water. For example, if the water is for irrigation, it should be analyzed for constituents that influence crop yields. If the water is for animal consumption, it should be analyzed for constituents that affect animal health.

d. Watershed projects

Small watershed projects present complicated circumstances in water-quality analysis, particularly in projecting any changes in the water quality of perennial streams. Water quality should be described in the present environmental conditions. Forecasting changes in water quality after project installation requires experience and judgment. For example, a watershed project may be planned for floodwater-retarding structures and alterations of the stream's configuration. Response to the environmental impact statement may be:

(1) For floodwater-retarding structures on perennial streams:
- (a) Will the impounded water change the base flow or the low flow $7Q_{10}$ of the stream? ($7Q_{10}$ is the symbol for the minimum unregulated streamflow that occurs for 7 consecutive days on a 10-year frequency.)
- (b) Will discharges from the impounded surface water elevate the stream's temperature? If so, how much?
- (c) If a submersed low-flow orifice is used to maintain the stream's temperature, at which depth should it be located and what will be the dissolved-oxygen level of the discharge? (If the orifice is near the bottom of a deep lake, the dissolved-oxygen level may be depressed and the plant-nutrient level may be high.)

(2) For channel improvement on perennial streams:
   (a) What change will occur in the stream's reaeration rate?
   (b) Will the modifications speed up the transfer of pollutants in the channel system and increase the waste load downstream?
   (c) How much temperature change can be expected if the stream's banks are cleared for construction?
   (d) Will the stream's water quality be reduced below the water-quality standards for fish and wildlife?

A review of these comments makes it obvious that projections of stream quality are needed but difficult to develop. Some states make descriptive statements about water quality based on data for present conditions but without specific figures on possible changes in water quality after the watershed project is installed. Descriptions of water quality should include data on dissolved oxygen, pH, suspended solids, temperature, turbidity, $7Q_{10}$, nitrogen, and phosphorus. Other parameters may be necessary, depending on conditions in the watershed.

3. <u>What is the availability of water-quality data that relate to the project under investigation?</u>

Although water-quality data are practically nonexistent for many streams, there are useful data on some selected streams. It is advisable to contact any agency that may have such information before beginning a water-quality study.

Almost every state has begun to study water quality by river basins within the state and to relate this information to discharges of treated and untreated waste water. These studies are required by EPA and are coordinated by the state water pollution control agency. If the needed water-quality data are not available, the regulatory agency may conduct the monitoring program or assist in analyzing the data. The regulatory agency may also assist SCS through consultation and review of water-quality data.

The U.S. Geological Survey (USGS) has a limited program for analyzing various water-quality parameters in some states. Most of the analyses are for major streams, but some USGS offices conduct extensive monitoring programs on a reimbursable basis with other agencies. USGS is also best qualified to provide data on $7Q_{10}$ flow rates.

Other sources, such as universities, river basin districts, Corps of Engineers, military installations, etc., may have some water-quality data.

4. <u>What visible factors in the drainage area influence water quality?</u>

A thorough field reconnaissance of the contributing drainage area is probably the most important step in developing a monitoring system. Knowledge of the physical characteristics of a drainage area provides guidance in determining sample points, water-quality parameters to analyze, major sources and types of pollution, stream conditions, and

the like. The quality of water in a stream or lake depends on the chemical, biological, and physical features of the drainage area.

Noting the features of a drainage area on a map helps in locating the most advantageous sampling points of a stream. Sampling points should be located both upstream and downstream from possible waste sources to identify the source's input. Figure 16-1 shows sampling point locations for a segment of a stream.

5. In what type of stream is the sampling to be conducted--ephemeral, intermittent, or perennial?

To monitor a stream properly, several samples should be collected from both base flow and flow resulting from surface runoff. Since Indian Creek is a perennial stream, base flow samples can be collected, but there is no base flow in Frog Branch except that from the potential waste source (subdivision). Therefore, sampling stations 1 and 4 will yield data for a base-flow analysis. During runoff events all stations should be sampled and flows measured to get an idea of possible waste loads from the potential waste source. This is illustrated further at the end of this section.

6. What is the necessary frequency and duration of sampling?

The frequency and duration of sampling depends on the size and complexity of the drainage area, climatic conditions, streamflow

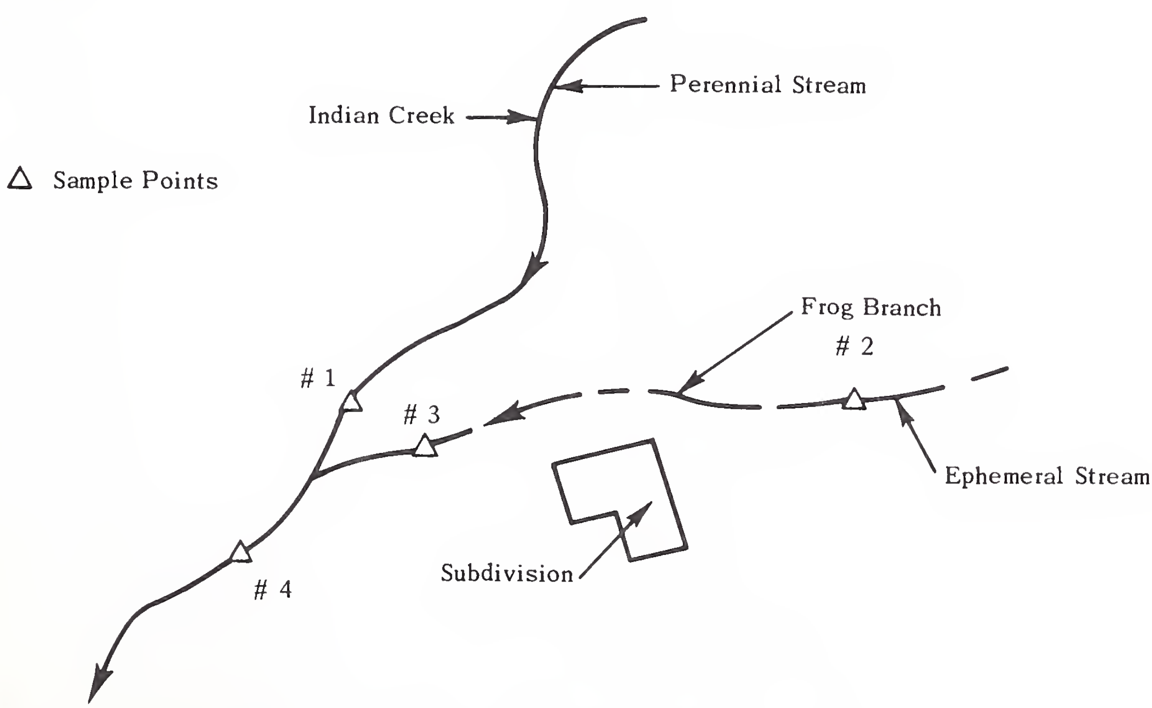

Figure 16-1.--Sampling stations on a stream segment.

characteristics, and the objective of the monitoring program. This is a judgment factor. Enough samples must be collected to estimate existing water quality for both base flow and flow resulting from runoff events. It may be possible to make such estimates with as few as four or five series of samples over a period of 1 or 2 months, or as many as 20 or more series of samples over a period of a year or longer may be needed. If the drainage area is small and covered with forest, four or five samples may be enough. If the drainage area is large with a wide variance in land use, a more extensive sampling and monitoring program is necessary.

METHOD OF COLLECTING SAMPLES

The results of any investigation that requires sampling are only as good as the method of sampling and analysis. If either the sampling or analysis is not done properly, the final report will be inaccurate and misleading. The samples collected should represent the actual field conditions. They should not be contaminated through mishandling.

A 1/2-gal plastic container, thoroughly clean, is usually satisfactory for collecting water for chemical and physical analyses. Most laboratories furnish containers that have been cleaned with a weak acid solution and thoroughly rinsed with demineralized water. The sample should be taken near the center of a stream or at least in the main flow. Some collectors use a rigid, light rod approximately 3 to 10 feet long for collecting samples. The container can be fastened to the rod, and the collector can extend his reach without extensive wading. For sampling lakes, a boat is probably necessary.

Water for bacterial analysis should be collected in a sterilized glass bottle (approximately 100 ml or larger) from a laboratory. Most laboratories have bottles especially for such samples. The collector must be extremely careful not to contaminate the inside of the bottle. It is best not to remove the cap of the bottle until just before the sample is collected. The mouth or opening of the bottle should not be touched when the cap is removed. The same care must be exercised when collecting the sample. The bottle should be submerged in the water and moved upstream in one motion to avoid floating particles and to prevent washing contamination from the hands into the bottle. As soon as the sample is collected, the cap should be replaced and tightened firmly. Samples should be protected by using recommended packaging and transportation procedures.

A tag should be attached to all sample bottles giving the station location and time of collection. Other vital information such as stream temperature, pH, and dissolved oxygen can be recorded in a log book or on the tag attached to the bottle. For accurate comparison of water quality from one sample point to another, the stream's discharge rate at each sample point should be measured. Available rainfall data should be recorded for determining the relationship of runoff to possible fluctuations in the various parameters.

ANALYZING THE WATER QUALITY DATA

The quality of water is not accurately described by measurements of a series of parameters. The complications and interactions of the parameters must also be considered. Persons without necessary experience or training should seek qualified assistance. Such assistance will help in getting a better understanding of water quality under normal conditions and the fluctuations in water quality under varying conditions.

This section does not attempt to discuss all the various aspects of interpreting water-quality data. Each region, state, or watershed has characteristics peculiar to the area. Only a brief summary of the parameters is given. It must be remembered that an onsite survey of the drainage area is necessary to get an accurate picture of water quality.

Dissolved Oxygen (DO)

The dissolved-oxygen content of pure water varies with the temperature of the water. The curve in figure 16-2 portrays the dissolved-oxygen saturation point in pure water at different temperatures at mean sea level (msl). Unpolluted surface water may have near-saturation values for the corresponding temperature and elevation. The dissolved-oxygen level can be depressed by:

1. Introduction of biodegradable wastes that increase the activity of aerobic bacteria,
2. Aquatic plant growth resulting from an increase in available nutrients such as carbon, nitrogen, and phosphorus (algae may raise the dissolved-oxygen level above the saturation point during favorable light intensity but depress it during the night, and
3. Injection of organic or inorganic compounds that require oxygen to complete their chemical reaction.

Turbidity

Turbidity is a measurement of the interference to light penetration in water caused by suspended matter that ranges in size from colloidal and fine materials to coarse grains, depending on the degree of turbulence. Turbidity in relatively quiescent lakes and streams is due mostly to colloidal particles, suspended clay, and silt. Turbidity in a body of water may be caused by substances that range from nearly all inorganic to nearly all organic. Turbidity is commonly expressed in Jackson turbidity units (JTU).

Turbidity affects the amount and depth of sunlight penetration into water, cost of water filtration for domestic consumption, effectiveness of disinfectant, and general appearance of the body of water. The amount of turbidity is usually related to the amount of soil eroded and its clay content, the amount of sewage solids, and various inorganic and organic substances that enter the water from the drainage area. Turbidity can also be generated within the stream by degradation of the channel.

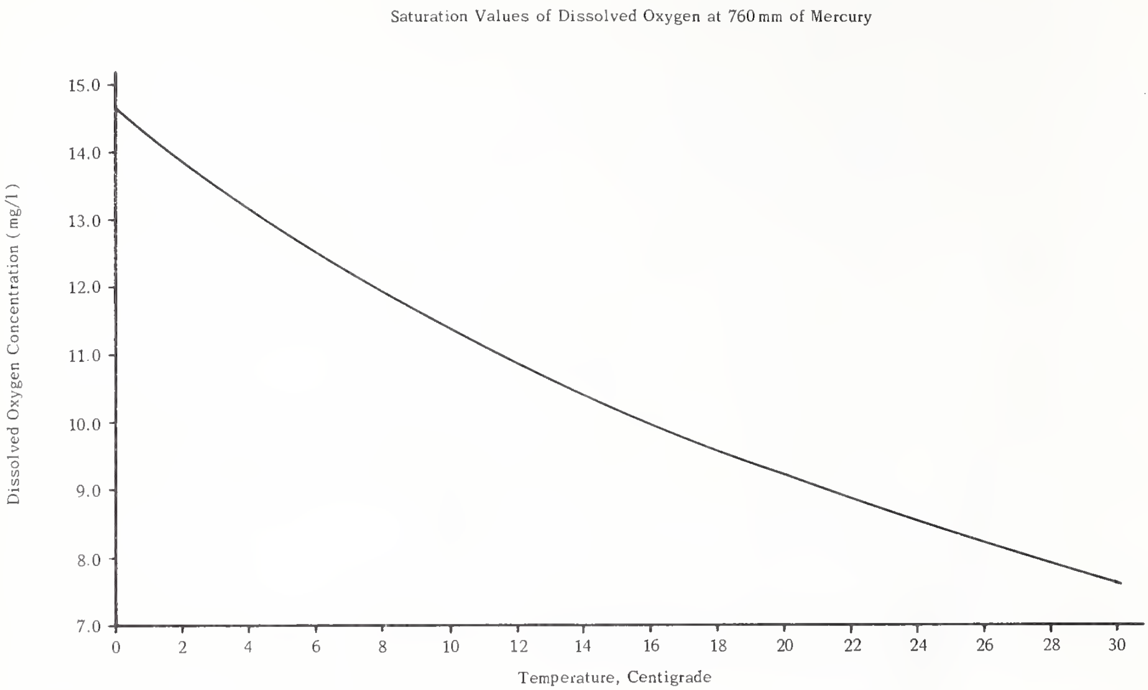

Figure 16-2.--Dissolved oxygen saturation in water vs. water temperature.

Color

Surface waters are often colored, especially those draining from swampy areas. The coloring is a result of contact of the water with organic debris such as leaves, wood, and the like in various stages of decomposition. The color comes from a variety of vegetable extracts. The principal color sources are tannins, humic acid, and humates from the decomposition of lignin. Also, color may be caused by industrial discharge such as that from dyeing or pulping. Color caused by suspended matter such as red clay particles is called apparent color. It is differentiated from color due to colloidal vegetable or organic extracts, which is called true color.

Apparent color is usually determined directly from the sample. To measure true color, a sample is usually contrifuged to separate any suspended solids and the measurements are made on the clarified liquor.

Measuring the color of a stream can give an idea of the origin of the water and its esthetic acceptability for human consumption and contact sports. If the color units are high, a thorough onsite field investigation should be conducted to identify the source.

The color in water from swampy areas is not harmful or toxic, but the water is generally not acceptable to the public as a source of drinking water without extensive treatment. Water intended for human consumption should not have a color measurement exceeding 20 platinum-cobalt standard units. For detailed information concerning units of color measurement and procedures for determination, contact someone

with experience or training in this field. The natural color of water can usually be removed by coagulation with a salt having a trivalent metallic ion.

pH

The pH of water is a measure of its hydrogen ion concentration and expresses its acidity or alkalinity. The pH value is an important factor in practically all phases of sanitary engineering and biology (aquatic and microscopic). On a pH scale of 0 to 14, a pH of 7.0 (neutral) is best for water treatment, body contact sports, wildlife, aquatic life, etc. Values below 7.0 indicate acid solutions; values above 7.0 indicate alkaline solutions.

1. Acidity

The pH and the carbon dioxide (CO_2) content of water should be measured in the field, since some of the CO_2 escapes to the atmosphere enroute to a laboratory for testing. Carbon dioxide depresses the pH but not lower than 4.5. A pH lower than 4.5 indicates the presence of a strong mineral acid in natural water or that an industrial waste is influencing the acidity. A stream that has numerous springs may have a high CO_2 concentration and subsequently a low pH. If a significant amount of organic matter is present in water, the pH may be influenced by the CO_2 produced as an end product of decomposition of the organic matter by bacteria.

2. Alkalinity

The alkalinity of natural waters is due primarily to bicarbonates from the action of CO_2 on basic minerals in the soil. If algae flourish in surface waters, carbonate and hydroxide alkalinity may occur and the pH may be as high as 9 to 10. Industrial discharges may also influence the alkalinity.

Biochemical Oxygen Demand (BOD)

The BOD parameter is used primarily to measure the organic strength of waste water, not to describe stream characteristics. Normally, a BOD determination is necessary only when an oxygen-consuming waste discharge is influencing the stream. The BOD of a natural stream is usually so low that a test is not accurate nor the results significant.

Nitrogen (N)

The primary importance of nitrogen in monitoring surface waters is that (1) the form of nitrogen tells how recently a stream has been polluted, (2) the amount of nitrate can be related to a possible health problem, and (3) the nitrogen concentration may indicate the possibility of nuisance algal blooms.

In streams freshly polluted by untreated sewage, nitrogen is in the form of organic (protein) N and ammonia. In time the organic N is converted to ammonia N, and later, if aerobic conditions exist, ammonia is oxidized to nitrites and then to nitrates. Thus the form of nitrogen in a stream indicates how recently the stream was polluted.

Various technical sources suggest general values for appraising the free ammonia content in surface waters. These values are: low concentration, 0.015 to 0.03 mg/l; moderate, 0.03 to 0.10 mg/l; and high, 0.10 mg/l or greater. One exception is the presence of ammonium sulfate of mineral origin. Nitrites, the first product of the oxidation of free ammonia, are practically nonexistent in unpolluted streams; therefore, their presence indicates pollution. Nitrates, the final product of the biochemical oxidation of ammonia, may be in streams in varying amounts and may indicate earlier pollution that has been removed through oxidation by the stream's self-purification ability. Nitrates may also be contributed by the organic material in eroded soils or by other nitrogenous sources such as commercial fertilizers. Drinking waters with a high nitrate content often cause methemoglobinemia in infants (blue babies), which is due to a lack of oxygen in the blood (see glossary and ch. 3). The maximum limit for nitrates in drinking water is 10 mg/l as N or 45 mg/l as NO_3.

Excessive plant nutrients in streams and lakes can create a nuisance aquatic plant growth such as algal bloom. A flourishing growth depends on an adequate supply of all the necessary elements, and nitrogen is only one of them. If the nitrogen source is related to organic waste, the other essential elements are usually available.

Phosphorus (P)

Phosphorus has been blamed for the abundant growth of aquatic vegetation, but phosphorus, like nitrogen, is not solely responsible. Phosphorus has been selected by some regulatory agencies as the one element from the group of elements essential to plants that can be controlled. The suggested limit for phosphorus in lakes is near 0.01 mg/l, but this limit depends on the availability of the other essential elements.

Uncontaminated streams may contain 0.01 to 0.03 mg/l total P in solution, although higher concentrations are found in streams that drain soils rich in phosphorus. Rainfall also may have a P concentration of 0.01 to 0.015 mg/l. Domestic sewage is relatively rich in phosphorus compounds. Before the development of synthetic detergents, inorganic phosphorus in domestic sewage usually ranged from 2 to 3 mg/l and organic forms from 0.5 to 1.0 mg/l. It is estimated that sewage now probably contains 3 to 5 mg/l inorganic phosphorus because of the polyphosphates in detergents.

The amount of available phosphorus in solution depends on the type and amount of sediment in the stream. Sediment with an affinity for phosphorus can remove almost all the phosphorus from solution.

Bacteria

A bacteriological study often provides the best information on the degree of pollution and the hazard to human health in a stream or lake.

But a routine analysis of water samples for all pathogenic bacteria is impossible. Therefore, indicator organisms are used to indicate fecal contamination. These are the fecal waste indicator organisms--total coliform, fecal coliform, and fecal streptococci.

1. Total coliform

Until recently the test for total coliform was used extensively for indicating the presence of fecal contamination. The test measures the concentration of total coliform bacteria in a volume of water and reports the results in number of coliform/per 100 ml. As the name indicates, the test measures all species of the coliform group and is not limited to the coliform species originating in the intestines of warm-blooded animals. Some coliform bacteria come from soil. Therefore, in stream analysis the results of this test are not always indicative of fecal contamination. The test can be applied to ground-water supplies because none of the coliform group is present in ground water unless it is contaminated.

Total coliform analysis is still conducted by many laboratories as a routine bacterial analysis. If the field reconnaissance and the water-quality surveys are thorough, a total coliform test can provide some indication of the degree of fecal contamination if the results are correlated with past water-quality studies.

2. Fecal coliform

The fecal coliform component of the coliform group can now be isolated by routine laboratory analysis. These organisms are relatively infrequent unless there is fecal pollution. The fecal coliform group survive a shorter time in natural waters than the coliform group as a whole; therefore, the presence of fecal coliform indicates relatively recent pollution. Also, the fecal coliforms do not multiply outside the intestines of warm-blooded animals.

There is no established correlation between the fecal coliform count and the total coliform count for evaluating the sanitary quality of water. In domestic sewage the fecal coliform density is usually more than 90 percent of the total coliform density, but in natural streams relatively free from recent pollution, the fecal coliform density may range from 10 to 30 percent of the total coliform density.

Most of the bacterial standards for streams are related to the allowable concentration of fecal coliform. For water contact sports, most states have a limit of 200 fecal coliform/100 ml as a maximum monthly geometric mean, and no more than 10 percent of the samples can exceed 400 fecal coliform/100 ml. These standards are based on frequent water sampling during a 30-day period.

Almost all natural waters have a fecal coliform concentration since all warm-blooded wildlife contribute. A thorough survey of the waste sources is necessary for interpreting the fecal coliform concentration. This is illustrated in the example given later.

3. Fecal streptococci

Fecal streptococci are streptococci commonly found in significant numbers in the feces of human or other warm-blooded animals. Since there are more data on fecal coliforms than on fecal streptococci and the analysis is fairly simple, the fecal coliform count is commonly used for continuous monitoring of water quality. The fecal streptococci count is used in conjunction with the fecal coliform count in sanitary surveys to get an indication of fecal sources.

Some of the merits of using fecal streptococci as indicators are that (1) they do not multiply in surface water, (2) they do not exist in pure water or virgin soil, and (3) they are not considered pathogenic.

Some limitations as indicators are that (1) their survival time versus that of pathogens is not known, (2) when waste is applied to soil, they disappear rapidly while coliforms survive for a long time, depending on the soil conditions, and (3) they grow under diverse conditions in nature, e.g., in food products or silage.

Using fecal streptococci as indicators of the sources of pollution is based on the ratio of fecal coliforms to fecal streptococci (FC/FS ratio) for bacteria excreted, as shown in table 16-1. Note that the FC/FS ratio for man is greater than 4.0 but that the FC/FS ratio for lower animals is less than 0.7. This ratio applied to field data may indicate whether the waste source is man or animal. The range from 0.7 to 4.0 is considered the "gray area," an indication of mixed waste sources. Some authorities consider the gray area to be from 1.0 to 3.0.

Interpretation of the FC/FS ratio requires extreme care. Many investigators apply this ratio only during the first 24 hours of flow in the stream from the waste source. The die-off rate of fecal coliforms and that of fecal streptococci differ; the fecal streptococci usually have a more rapid die-off rate. Also, if the bacterial population is low (less than 1,000 FC/100 ml), the ratio should be used with caution. If the pH is lower than 4.0 or higher than 9.0, the ratio should not be used.

Table 16-1.--Average density of indicators excreted in 24 hours

Animal	Fecal coliforms	Fecal streptococci	FC/FS ratio
	Million/100 ml	Million/100 ml	
Man	13.0	3.0	4.4
Duck	33.0	54.0	0.6
Sheep	16.0	38.0	0.4
Chicken	1.3	3.4	0.4
Cow	.23	1.3	0.2
Turkey	.29	2.8	0.1
Pig	3.3	84.0	0.04

3. EXAMPLE OF MONITORING AND SAMPLING

The PL-566 watershed shown of figure 16-3 is used to illustrate some of the principles that have been discussed. The following information was gathered in a field reconnaissance by the watershed planning party.

Drainage area: 10,000 acres
Average annual rainfall: 55 inches
Average annual runoff: 16 to 18 inches
Lake proposed for recreation:
    Surface area: 600 acres
    Permanent storage: 4,800 acre-feet
Present land use in drainage area:
    Woodland: 75 percent
    Pasture: 10 percent
    Row crops: 5 percent

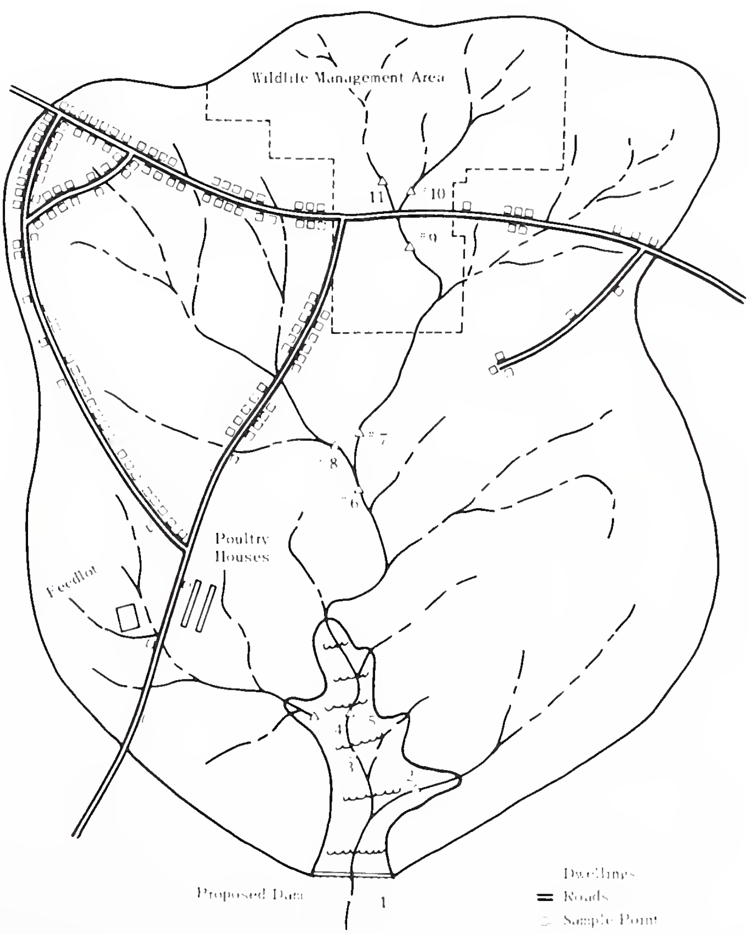

Figure 16-3.--Example of a watershed studied for water quality.

Idle: 5 percent
Miscellaneous: 5 percent
Poultry farm (broilers): one (capacity for 60,000 birds)
Feedlot: one (500 head cattle for winter feeding, November to March)
Homes in area: 150--25, modern construction; 80, 5 to 15 years old; 45, older than 15 years (information from field observation and field office data)

Since the plans include construction of a lake for recreation, the primary emphasis normally would be on a bacteriological study of the drainage area unless the water-quality records for the general area indicate that other physical and chemical factors may affect desirability for recreation. Samples should be collected at two or three stations to verify the chemical and physical water-quality characteristics. If the analyses of the first series of samples indicate a need for additional samples, these can be collected during the remainder of the monitoring period.

For adequate monitoring of the quality of water from a drainage area, more than three series of samples should be collected. Each series should be studied to determine any adjustments needed in the monitoring program. The data in table 16-2 give the analyses of the first three series of samples for this drainage area. A drastic change occurs in the third series, which were collected during a runoff event; therefore, close review of the data and correlating them to field conditions are necessary before taking any more samples.

ANALYSIS OF WATER QUALITY DATA

Bacteriological Data

As stated prviously, emphasis is on the bacterial population. The first two series of samples, taken from the base flow, did not reveal any substantial pollution. The FC/FS ratio of the first two series indicates that the waste sources are primarily lower animals. This indication can be misleading, however, since the counts are low. Many experienced investigators prefer not to use the FC/FS ratio if the fecal coliform count is below 1,000 FC/100 ml and definitely do not use the ratio if the count is below 500 FC/100 ml. Since this is a base flow with a low bacteria count, it may be wise to omit the FC/FS ratio except at station 4. The bacteria counts at station No. 4 are elevated, and the FC/FS ratio indicates that the waste source is nonhuman. The map shows that poultry and feedlot facilities drain into the tributary above station 4. If there is a base flow near these waste sources, three additional sampling stations should be used--one above both sources, one between the two sources, and one below both sources. Samples taken at these stations can identify the source of the discharge to the stream.

In the third series of samples, collected during a runoff event, the fecal coliform and fecal streptococcal populations were substantially elevated. An increase in bacterial density is expected during runoff, but density depends on the particular time--early, middle, or

Table 16-2.--Analyses of samples collected at 11 sampling stations
[---indicates tests not run]

Sampling station and series	Stream flow	Temperature	Fecal coliform per 100 ml	Fecal strepto-cocci per 100 ml	FC/FS	Dissolved oxygen	pH	Suspended solids	Total Kjeldahl nitrogen	Nitrite	Nitrate	Phosphorus
	cfs	°F	Count	Count		Pct. of saturation		mg/l	mg/l	mg/l	mg/l	mg/l
Station No. 1:												
Series 1--------	2.0	83	300	375	0.8	93	6.9	50	0	0	0.2	0.4
Series 2--------	1.6	85	220	421	.52	96	7.0	100	.03	0	.3	.1
Series 3--------	13.0	78	18,000	25,000	.72	100	7.1	700	.2	.05	1.5	1.0
Station No. 2:												
Series 1-------	.3	80	15	22	.7	---	---	---	---	---	---	---
Series 2-------	.1	82	20	33	.6	---	---	---	---	---	---	---
Series 3-------	1.0	77	100	170	.5	---	---	---	---	---	---	---
Station No. 3:												
Series 1-------	1.8	83	350	450	.8	---	---	---	---	---	---	---
Series 2-------	1.6	85	250	500	.5	---	---	---	---	---	---	---
Series 3-------	12.4	78	25,000	35,000	.71	---	---	---	---	---	---	---
Station No. 4:												
Series 1-------	.4	82	700	1,300	.5	---	---	---	---	---	---	---
Series 2-------	.3	86	810	1,650	.5	---	---	---	---	---	---	---
Series 3-------	2.0	88	45,000	>50,000	<1.0	---	---	---	---	---	---	---
Station No. 5:												
Series 1-------	1.4	84	150	100	1.5	---	---	---	---	---	---	---
Series 2-------	1.3	85	100	50	2.0	---	---	---	---	---	---	---
Series 3-------	10.7	78	1,000	350	2.9	---	---	---	---	---	---	---
Station No. 6:												
Series 1-------	1.3	81	300	100	3.0	94	6.8	35	0	0	0.1	0.3
Series 2-------	1.2	83	275	150	1.8	99	6.9	80	0	0	0.15	0.1
Series 3-------	10.0	74	3,000	650	4.6	99	7.0	12,000	0.03	0	0.5	0.9
Station No. 7:												
Series 1-------	.8	80	50	100	.5	---	---	---	---	---	---	---
Series 2-------	.7	82	60	90	.7	---	---	---	---	---	---	---
Series 3-------	6.0	74	800	1,100	.7	---	---	---	---	---	---	---
Station No. 8 :												
Series 1-------	.5	82	500	100	5.0	---	---	---	---	---	---	---
Series 2-------	.5	84	480	80	6.0	---	---	---	---	---	---	---
Series 3-------	4.0	74	5,000	1,200	4.2	---	---	---	---	---	---	---
Station No. 9:												
Series 1-------	.3	80	100	200	.5	---	---	---	---	---	---	---
Series 2-------	.3	81	110	100	1.1	---	---	---	---	---	---	---
Series 3-------	2.5	74	950	1,600	.6	---	---	---	---	---	---	---
Station No. 10:												
Series 1-------	.1	80	20	40	.5	---	---	---	---	---	---	---
Series 2-------	.2	81	50	80	.6	---	---	---	---	---	---	---
Series 3-------	1.5	74	400	740	.5	---	---	---	---	---	---	---
Station No. 11:												
Series 1-------	.1	79	50	10	5.0	---	---	---	---	---	---	---
Series 2-------	.1	80	30	25	1.2	---	---	---	---	---	---	---
Series 3-------	1.0	73	1,100	2,000	.55	---	---	---	---	---	---	---

late--the samples were collected during the runoff event and on the degree of pollution (fig. 16-4). Although a large number of samples need to be collected and analyzed, bacterial density versus runoff curves should be developed for one runoff event whenever possible. If the waste sources are primarily wildlife, the bacterial population should not be elevated to an abnormal density unless a high percentage of the rainfall results in runoff. Because of its diluting effect, the amount of base flow in a stream also affects bacterial density.

The bacterial population at station 1 increased to an abnormal density during the runoff event, and the FC/FS ratio indicates a non-human source. The count at station 3 is even higher than that at station 1, indicating a possible combination of bacterial die-off between stations 3 and 1, dilution by runoff from station 2, or the different time of collection during runoff (fig. 16-4). Samples from station 4

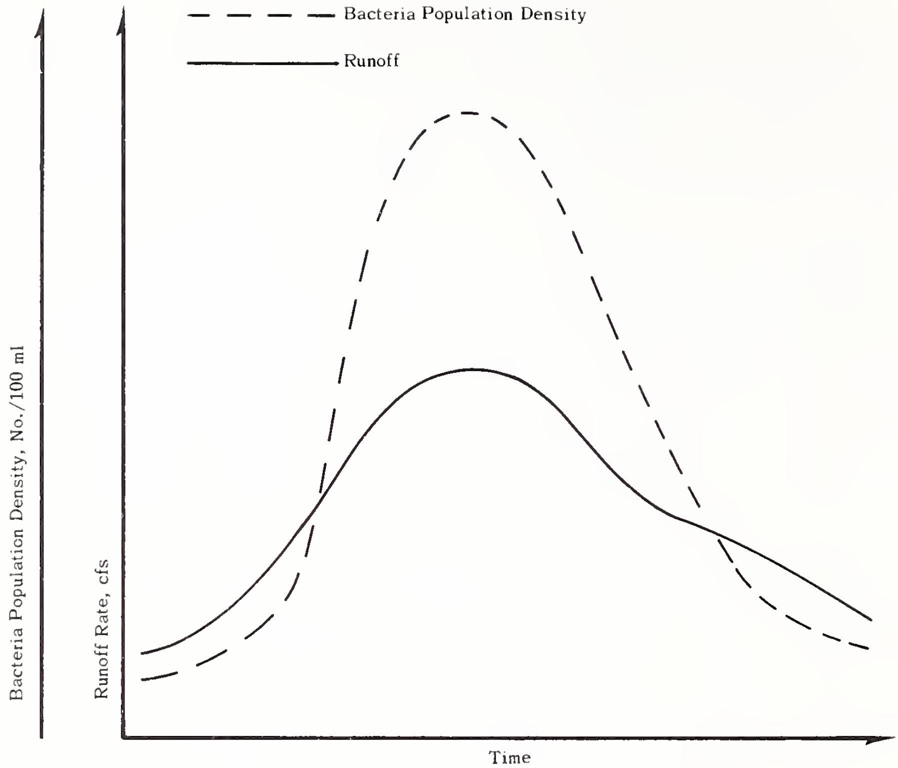

Figure 16-4.--Bacterial density and runoff curve.

give the best indication of the waste source. The FC/FS ratio indicates a nonhuman source and, from a review of figure 16-3, it is possible to conclude that the two livestock confinement units are the sources.

To verify that the livestock units are the waste sources, additional stations for sampling runoff should be installed to determine if the waste is from the confinement areas, from manure-spreading areas, or from other sources such as wildlife areas. A comparison of samples from stations 5, 6, and 8 indicates that the human population is contributing to the fecal coliform count but that the density is reduced as stream distance increases. A comparison of samples from stations 9 and 11 shows that the increased bacterial density is probably from wildlive since the area is a wildlife management area and few domestic animals are likely to be present.

Present indications are that the swimming beach should be located on the east side of the proposed recreation lake between stations 2 and 1 (see fig. 16-1). This location allows the maximum amount of dilution and bacterial die-off in the lake. Corrective action should be taken on problem waste sources before an impoundment for water is constructed. Stream monitoring should be continued after the corrective action is taken to be sure that the sources of pollution are eliminated.

Another approach is to apply a mixing equation when enough samples have been collected. The equation will give an approximation of the

bacterial concentration in the lake after a runoff event. The information obtained from the mixing equation cannot be used as concrete evidence of the bacterial effect on a lake or stream because only grab samples are analyzed and uniform mixing is assumed. The information may serve as a guide.

The mixing equation is:

$$B.Q. = \frac{C_1 Q_1 + C_2 Q_2}{Q_1 + Q_2}$$

where

B.Q. = average bacterial population in a body of water after a runoff event
C_1 = mean fecal coliform density of runoff
Q_1 = acre-feet of runoff entering a lake or stream
C_2 = mean fecal coliform density in a lake or stream before the runoff event
Q_2 = acre-feet of water in the lake or stream.

This equation assumes instantaneous, complete mixing of the runoff water with the water in a lake or stream although this condition will not exist. The counts will be higher near the inlets into the lake or stream and lower the greater the distance from the waste sources.

This equation is often applied in two different ways. One approach is to calculate the average fecal coliform concentration in a lake from the mean inflow concentration. Another approach is to calculate the maximum allowable geometric mean of fecal coliform inflow from runoff.

The following example illustrates the second approach. Consider the conditions given for the watershed and assume that

Q_1 = 2,500 acre-feet
Q_2 = 4,800 acre-feet (storage in lake)
C_1 = mean fecal coliform density in runoff
C_2 = 50 FC/100 ml in the lake before runoff occurs (assumed)
B.Q. = 200 FC/100 ml maximum geometric mean/per month for water contact sports

$$200 = \frac{2{,}500\ C_1 + 50\ (4{,}800)}{2{,}500 + 4{,}800}$$

C_1 = 488 FC/100 ml (allowable fecal coliform density in the storm runoff)

As an example of the first approach, assume that the mean FC count from a rainstorm is 800 FC/100 ml. Runoff from the 10,000-acre watershed is 0.8 inches.

$$Q_1 = \frac{0.8}{12} \times 10{,}000 = 666 \text{ acre-feet}$$

C_1 = 800 FC/100 ml
Q_2 = 4,800 acre-feet
C_2 = 50 FC/100 ml (assumed)

$$B.Q. = \frac{800\ (666) + 50\ (4{,}800)}{666 + 4{,}800} = \frac{772{,}800}{5{,}466}$$

B.Q. = 141 FC/100 ml

The mean fecal coliform count should be determined from a monitoring period that covers several series of samples. It should not be used as concrete evidence for acceptance of a site but should be used with other data as an indication of the potential acceptability of a site. An analysis may indicate an average fecal coliform density in a lake of 250 FC/100 ml, but if the beach area is located away from sources of pollution, it may be reasonable to conclude that the concentration will be less than 200 FC/100 ml at the beach area because of bacterial die-off and dilution between the stream inlet and the beach.

Chemical and Physical Data

Chemical and physical analyses of samples taken at stations 1 and 6 indicate the water quality in the upper and lower reaches of the stream. If the parameters reflect an unusual condition, additional samples should be collected to determine the source of pollution. The parameters used in this example are not all inclusive; often samples should be analyzed for more parameters. Carbon dioxide, turbidity, color, chemical oxygen demand, etc., are frequently included in a water quality analysis. Figure 16-1, table 16-2, and the discussion that follows illustrate the analytical principles but do not provide a detailed analysis of each possible parameter. Only eight parameters are used.

Temperature

Knowing the fluctuation in water temperature is important in determining the concentration of dissolved oxygen at 100-percent saturation. The stream selected for this example is in the Deep South and has little overhanging cover to provide shade. The runoff water is approximately 3 to 6 degrees (^{o}F) cooler than the base flow in the stream, which can be expected from forested areas.

If this analysis of temperature is applied to a stream for which channel improvements are planned, a record should be kept of the temperature fluctuations during the hottest weather of the year. Air and water temperatures should be taken and recorded at the same time to have a good temperature baseline for comparison after the channel improvements are made. Although these data are often lacking, they are important for future projects.

Dissolved Oxygen (DO)

For comparison of one series of samples with another, it is usually better to represent the dissolved oxygen concentration as the percentage of that at saturation. Dissolved oxygen saturation varies with water temperature and elevation above mean sea level (msl).

The data in table 16-2 indicate no substantial variance in DO concentration that would suggest a significant load of organic pollution. The increase in DO concentration in the surface runoff water is due to stream reaeration. In areas of overfalls or steep, rocky channels, the DO concentration may be higher than the 100-percent saturation level. If the DO level had dropped, it would suggest that an organic waste load had washed into the stream or that a heavy bottom deposit of organic material had gone into suspension.

pH

The pH is slightly depressed, which may be due to the carbon dioxide level in the water or to sources of acidity that can occur in spring-fed streams. It is not uncommon to find the pH fluctuating between 6.0 and 8.0, depending on the water source. The water may come from the ground into the stream with a high carbon dioxide level and a depressed pH, but as the carbon dioxide escapes to the atmosphere, the pH increases toward neutral.

Suspended Solids

The suspended solids parameter represents the concentration of soils and organic and inorganic material in suspension. The level of suspended solids for the base flow in this example is satisfactory, but it is substantially increased in the third series of samples (surface runoff).

Note that the suspended solids level is higher at station 6 than at station 1, which indicates that the upper reaches of the watershed have a source of sediment either in stream degradation or in the surrounding land area, or both. Since the concentration is lower at station 1, there may be enough reduction in stream velocity to allow some settling of suspended solids between the two stations. The lower concentration may also indicate that the bulk of suspended material had not arrived at station 1 when it was sampled. To fully explain the difference in concentration would require a series of samples taken during a runoff event.

Nitrogen (N)

Determination of the total nitrogen concentration requires three different tests. The total Kjeldahl nitrogen test measures the ammonia and organic nitrogen forms of nitrogen. The regular Kjeldahl nitrogen test measures only organic nitrogen but not ammonia. Free ammonia in surface water indicates fresh pollution. The third series of samples reflects fresh pollution, especially at station 1. The source may be the animal confinement areas.

Since nitrites represent the first product of the oxidation of free ammonia, the presence of nitrites (0.05 mg/l) indicates organic waste that has already gone through some degree of decomposition. Thus, the pollution indicated is not necessarily fresh pollution.

The nitrate concentration varies with land use in a drainage area and with geological erosion. Nitrates can indicate possible previous pollution with the nitrogen already reduced to its final mineral form. The present nitrate concentration is not unusual except at station 1 during runoff. This unusual concentration could be due to the animal confinement area, but that is not definite since nitrates generally are present to some degree in surface water.

Phosphorus (P)

The phosphorus concentration is fairly high, which could be attributed to the P-rich soil eroded from the drainage area or to a waste discharge, but other sources should not be discounted. The high P level at both sampling stations and the increase during runoff are further

indications that the source is eroded soil. Since the suspended solids level is substantially higher at station 6 than at station 1, it can be deduced that the P content would also be higher, but this depends on the affinity of the suspended solids for phosphorus. If the suspended solids have a definite affinity for phosphorus, then the solids may adsorb part of it, leaving less in solution.

SUMMARY OF EXAMPLE

This example illustrates the methodology for conducting a water-quality monitoring program. It used three series of samples, which are enough for only the beginning of a good monitoring system. At least five or six additional series are needed to further describe water quality. Additional sampling stations are also needed to evaluate the waste sources.

Although only three series of samples are used in this example, the analyses indicate that the proposed site is not satisfactory for impounding water for water contact sports. The fecal coliform concentration in the runoff from the feedlot or the poultry houses, or both, is too high. Extending the monitoring program with additional sampling stations and monitoring a few runoff events should isolate and identify the specific source of the high coliform concentration. Corrective steps should be taken to reduce the concentration and the stream monitored again to determine acceptability of the water for water contact sports.

The chemical quality is not unusual. The presence of suspended solids indicates a possible source of solids above station 6, and the total Kjeldahl nitrogen test indicates a waste source between stations 1 and 6. It is also indicated that storm runoff usually increases the concentration of most parameters.

CONCLUSION

The investigator planning a water-quality monitoring system should request suggestions and criticism from reviewing and regulatory agencies. A water-quality monitoring program requires research, vigilance, and experience. The data should be summarized and reasons given for any fluctuations. Most of these reasons can be keyed to the first field reconnaissance of the drainage area, one of the most important elements in monitoring water quality.

4. MONITORING AND SAMPLING OF ANIMAL WASTE DISPOSAL SYSTEMS

After a waste management system has been designed, approved, and constructed, it must be monitored continuously to determine effectiveness. Some guidelines for monitoring seepage from earth storage facilities and lagoons, constituents of stored wastes, constituents in soils and crops receiving waste water, and efficiency of treatment systems for animal wastes are discussed in the following pages.

For waste disposal systems, sampling and monitoring are defined as follows:

1. Sampling is the physical act of collecting water, waste water, soil, or vegetation for the purpose of analysis or analyses for various constituents.
2. Monitoring is a program of sampling and observing the analytical data to determine effectiveness of a system and fluctuations in the various constituents under surveillance. This may be a continuous process.

SEEPAGE FROM EARTH STORAGE FACILITIES AND LAGOONS

If earth storage facilities or lagoons are used to retain animal waste, seepage through the soil should be reviewed critically. Studies indicate that earth storage facilities are soon sealed with animal waste, but it may be a mistake to assume that there is no risk of pollution. It may be a few weeks or several months before the soil is adequately sealed with manure, and during this time nitrates and other undesirable constituents can enter the ground water. If a manure storage facility or waste lagoon is to be constructed in a soil with a questionable seepage stratum, approval should be obtained from the state regulatory agency and a ground-water monitoring system installed to detect possible problems.

If the direction of ground-water flow is known, monitoring a small well to ground-water level is enough. But the direction of ground-water flow is difficult to determine from surface observation. Ground-water wells should be located on all sides of the facility to be sure that one well is on the downstream side of the underground flow. Ground water does not necessarily flow parallel to the slope of the ground surface (see fig. 16-5).

When the wells are installed, several series of samples should be collected from the ground water for analysis before the facility is loaded with animal waste. The wells should be protected from contamination by surface water. Enough samples should be taken to develop a base line for constitutents of the ground water. Samples are usually analyzed for the same chemical parameters that are measured in raw-water supplies for human consumption, such as the various forms of nitrogen, phosphorus, iron, manganese, copper, etc., but they may also need to be analyzed for other constitutents.

After the ground-water base line is established, animal waste can be added to the storage facility and monitoring begun. The frequency of sampling depends on the amount of seepage expected. An analysis to determine the amount of seepage and the rate of travel is helpful in setting a sampling routine. At the beginning of the monitoring program, frequency of collecting samples can range from once every 2 or 3 days to once every 2 weeks. From the seepage analysis the travel time from the storage facility to the well on the downstream side can be calculated. If there is no pollution for a reasonable period after the calculated travel time has elapsed, frequency of sampling can be reduced. It is desirable to continue some type of monitoring program as long as

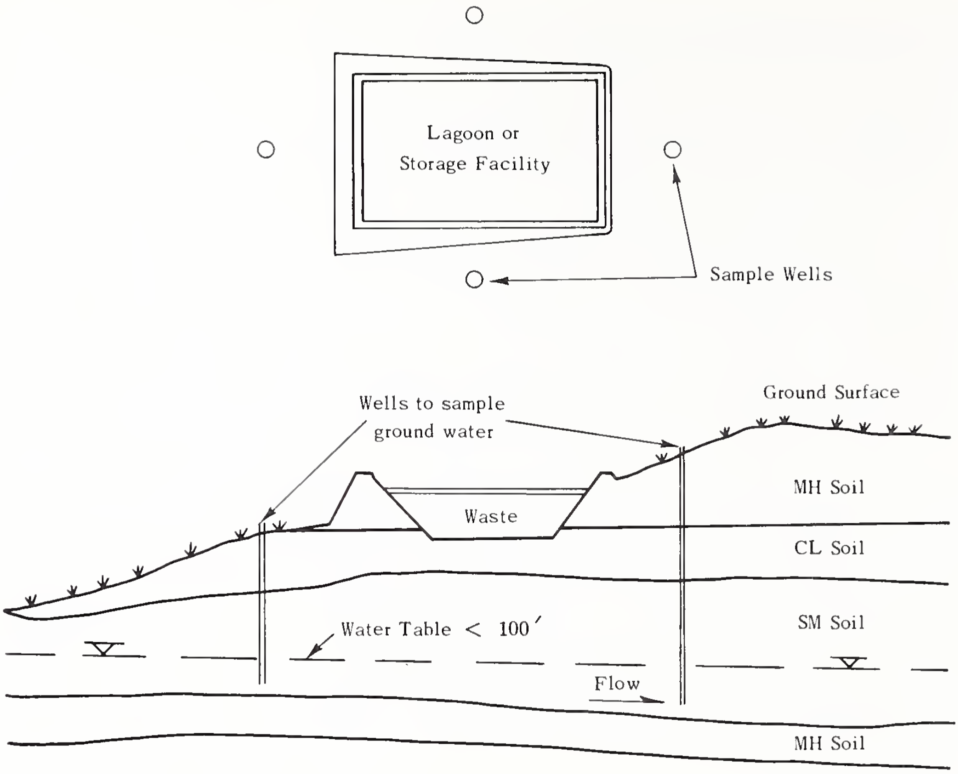

Figure 16-5.--Location of monitoring wells.

the facility is used or contains decaying organic material. Frequency of sampling eventually can be reduced to once or twice a year if there is no evidence of ground-water pollution after several years of monitoring. Fecal coliform bacteria are not usually detected in ground water because the bacteria have a high die-off rate in soils.

If the storage facility is constructed in slowly permeable or heavy clay soil, then a ground-water monitoring system may not be necessary. Seepage control is better than monitoring ground water for possible seepage. If monitoring indicates that the ground water is being polluted, the facility should not be used until the source of pollution is eliminated.

CONSTITUENTS OF STORED WASTE

The field application rate recommended for animal wastes is usually based on the nitrogen content of the wastes. If wastes are stored for only a few days, it is commonly assumed that little nitrogen is lost and the application rate is based on the nitrogen content of the manure as excreted by the animal.

If wastes are stored for longer periods, the nitrogen content may change appreciably, especially if there are aerobic and anaerobic strata in the storage facility or lagoon. The owner of a waste storage facility may wish to take several series of samples to determine the plant nutrient content of the waste before field application. If waste

water is applied by sprinklers, sampling of the water to determine nitrogen loss during irrigation may be wise. This requires catching the liquid in a container as it is applied.

CONSTITUENTS IN SOILS AND CROPS RECEIVING WASTE WATER

Many waste components applied in excess can be harmful to soils or plants and may be toxic to animals consuming vegetation that has taken up excessive amounts.

It is estimated, for instance, that only half of the nitrogen in animal manure becomes available to plants during the first year and that the remainder becomes available at reduced rates in subsequent years. A high rate of annual application may be safe for the first year or so, but continued application at that rate could result in nitrogen being leached to ground water as nitrates or being taken up in excess by plants. Under certain conditions an excess of nitrates in forage causes grass tetany in animals.

Dissolved salts in waste water may be leached to ground water or, in arid areas, may build up in soils to a level that is toxic to certain plants. Too much sodium can disperse certain soils and affect plant growth adversely. Zinc, copper, and nickel can build up in soils and become toxic to vegetation. Arsenic, boron, cadmium, lead, mercury, molybdenum, and selenium in excessive amounts are toxic to both plants and animals. Elements such as lead and mercury are cumulative and over time can build up to levels toxic to animals.

Chapters 2, 5, and 6 discuss the recommended maximum concentration of the various elements in water for different uses and the effects of an excess of waste components on soils and plants. Monitoring of applied wastes, soils, and plants may be required for safe management of disposal areas that receive heavy waste applications or wastes with high concentrations of troublesome components. Assistance of soil scientists, agronomists, and geologists is necessary for establishing and evaluating such monitoring programs.

EFFICIENCY OF ANIMAL WASTE TREATMENT SYSTEMS

To monitor the efficiency of a waste-water treatment system, samples should be taken of the raw waste water, of the waste at locations between treatment units, and of the discharge. Regulatory agencies usually do not allow any discharge from animal waste treatment systems, but if discharge is allowed, the owner is usually required to have routine analyses made to be sure that the treatment unit is functioning properly. The analyses are reported to the regulatory agency. Most animal waste treatment systems provide for final disposal of the effluent on land. The effluent is treated to control odor, to reduce volume or organic content, or merely to provide inoffensive storage. Monitoring of treatment efficiency is important for determining the land application rate and for correcting possible malfunctions within the treatment system.

The constituents normally monitored are BOD, chemical oxygen demand, forms of nitrogen, phosphorus, potassium, dissolved oxygen,

suspended solids, and chemicals used in animal feed that can disrupt treatment efficiency. But a monitoring system has no value if the data are not properly analyzed.

The owner of a facility is responsible for the proper functioning of the treatment or disposal system, and fulfilling this responsibility often requires a monitoring program. Monitoring benefits both the owner and the public.

Sampling water, vegetation, or soil and recording the data do not complete a monitoring system. The data must be analyzed in relation to the various effects the constituents can have upon the environment. The owner may need the assistance of engineers, agronomists, geologists, and soil scientists in establishing a monitoring program and developing a system for analyzing accumulated data.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

CONVERSION FACTORS AND TABLES

Compiled by Bishop C. Beville, sanitary engineer,
SCS, Gainesville, Fla.

1. LENGTH

Unit of measure	Symbol
millimeter	mm
centimeter	cm
meter	m
kilometer	km
inch	in
foot	ft
mile	mi

CONVERSION TABLE

mm	cm	m	km	in	ft	mi
1	0.1	0.001	---	0.0394	0.003	---
10	1	0.01	---	0.394	0.033	---
1000	100	1	0.001	39.37	3.281	---
---	---	1000	1	---	3,281	0.621
25.4	2.54	0.0254	---	1	0.083	---
305.8	30.58	0.306	---	12	1	---
---	---	1609	1.609	---	5280	1

2. AREA

Unit of measure	Symbol
square meter	m^2
hectare	ha
square kilometer	km^2
square foot	ft^2
acre	acre
square mile	mi^2

CONVERSION TABLE

m^2	ha	km^2	ft^2	acre	mi^2
---	---	---	---	640	1
1	---	---	10.76	---	---
10,000	1	0.01	107,600	2.47	0.00386
$1x10^6$	100	1	---	247	0.386
0.093	---	---	1	---	---
4,050	0.405	---	43,560	1	0.00156
---	259	2.59	---	640	1

3. VOLUME

Unit of measure	Symbol
cubic kilometer	km^3
cubic meter	m^3
liter	l
million U.S. gallons	Mgal
acre-foot	acre-ft
cubic foot	ft^3
gallon	gal

CONVERSION TABLE

km^3	m^3	l	Mgal	acre-ft	ft^3	gal
1	$1x10^9$	---	---	811,000	---	---
---	1	1000	---	---	35.3	264
---	0.001	1	---	---	0.0353	0.264
---	---	---	1	3.07	134,000	$1x10^6$
---	1,233	---	0.3259	1	43,560	325,900
---	0.0283	28.3	---	---	1	7.48
---	---	3.785	---	---	0.134	1

4. FLOW RATE

Unit of measure	Symbol
cubic kilometers/year	km^3/yr
cubic meters/second	m^3/s (m^3/sec)
liters/second	l/s (l/sec)
million U.S. gallons/day	mgd (Mgal/d)
U.S. gallons/minute	gpm (gal/min)
cubic feet/second	cfs (ft^3/s)
acre-feet/day	acre-ft/day

CONVERSION TABLE

km^3/yr	m^3/s	l/s	mgd	gpm	cfs	acre-ft/day
1	31.7	---	723	---	1,119	2,220
0.0316	1	1000	22.8	15,800	35.3	70.1
---	0.001	1	0.0228	15.8	0.0353	(0.070)
---	0.044	43.8	1	694	1.547	3.07
---	---	0.063	---	1	0.0022	0.0044
---	0.0283	28.3	0.647	449	1	1.985
---	---	14.26	0.326	226.3	0.504	1

5. WEIGHT

Unit of measure	Symbol
ton (short)	T
pound	lb
kilogram	kg
gram	g
milligram	mg
microgram	μg

CONVERSION TABLE

T	lb	kg	g	mg	μg
1	2000	907	---	---	---
	1	0.454	453.592	---	---
	2.205	1	1000	1×10^6	---
		0.001	1	1000	1×10^6
			0.001	1	1000
				0.001	1

NOTE:

1 short ton = 2,000 lb
1 long ton = 2,240 lb
1 metric ton = 1,000,000 g = 1,000 kg = 2,205 lb

6. MISCELLANEOUS

1 acre-inch = 27,154 gallons
1 horsepower = 0.746 kilowatts
1 horsepower = 550 foot-pounds per second
degrees C = 5/9 (F^o - 32^o)
degrees F = 9/5 C^o + 32^o
1 gram = 15.43 grains
1 ppm = 8.345 pounds per million gallons of water
1 U.S. gallon = 8.345 pounds

parts per million (ppm)

1 ppm is 1 part by weight in 1 million parts by weight.

milligrams per liter (mg/l)

1 mg/l is 1 milligram (weight) in 1 million parts (volume), i.e., 1 liter. Therefore, ppm = mg/l when a solution has the same specific gravity as water. Usually, substances in solution up to concentrations of about 7,000 mg/l do not materially change the specific gravity of water. To that limit ppm and mg/l are numerically interchangeable. A 1-percent solution has a concentration of 10,000 ppm.

Electrical conductivity

Electrical conductance is expressed in mhos (reciprocal ohms); electrical conductivity (EC) is expressed in mhos/cm. 1 mho/cm = 1,000 millimhos/cm (mmhos/cm) = 1,000,000 micromhos per centimeter (μmhos/cm). 1.0 mmho/cm equals a concentration of approximately 640 ppm dissolved salts.

AGRICULTURAL WASTE MANAGEMENT FIELD MANUAL

GLOSSARY

Compiled by Bishop C. Beville, sanitary engineer,
SCS, Gainesville, Fla.

Contents

GLOSSARY

1. ANIMAL WASTE MANAGEMENT TERMS

Aeration.--Intimate contact between air and a liquid effected by bubbling air through the liquid or by agitation of the liquid to promote surface absorption of air.

Aerobic.--Living or active only in the presence of oxygen.

Aerobic bacteria.--Bacteria that require the presence of free (dissolved or molecular) oxygen for their metabolic processes. (Oxygen in chemical combination will not support aerobic organisms.)

Aerobic decomposition.--Reduction of the net energy level of organic matter by aerobic micro-organisms.

Agricultural waste.--Wastes produced that have their origin from agriculture. Most such wastes are associated with the production of food and fiber on farms, ranges, and forests. These wastes normally include animal manure, crop residues, dead animals, and agricultural chemicals. Municipal solid wastes, effluents, and sludges disposed of in agricultural areas are considered agriculture-related wastes in this manual.

Algae.--Primitive plants, one- or many-celled, usually aquatic and capable of synthesizing their food by photosynthesis.

Alkalinity.--A quantitative measure of the capacity of liquids or suspensions to neutralize strong acids or to resist the establishment of acidic conditions. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, volatile acids, salts, and occasionally of borates, silicates, and phosphates. Numerically, it is expressed in terms of the concentration of calcium carbonates that have an equivalent capacity to neutralize strong acids.

Anaerobic.--Living or active in the absence of oxygen.

Anaerobic bacteria.--Bacteria that do not require the presence of free or dissolved oxygen for metabolism.

Anaerobic decomposition.--Reduction of the net energy level and change in chemical composition of organic matter caused by micro-organisms in an anaerobic environment.

Bacteria.--Primitive plants, generally free of pigment, which reproduce by dividing in one, two, or three planes. They occur as single cells, chains, filaments, well-oriented groups, or amorphous masses. Most bacteria do not require light, but a limited number are photosynthetic and draw upon light for energy. Most bacteria are heterothrophic (utilize organic matter for energy and for growth materials), but a few are autotrophic and derive their bodily needs from inorganic materials.

Bedding.--Material, usually organic, placed on the floor surface of livestock buildings for animal comfort and to absorb urine and other liquids and promote cleanliness in the building.

BOD (Biochemical Oxygen Demand).--An indirect measure of the concentration of biologically degradable material present in organic wastes; the amount of free oxygen utilized by aerobic organisms when allowed to attack the organic matter in an aerobically maintained environment at a specified temperature ($20^{o}C$) for a specific time period (5 days). It is expressed in milligrams of oxygen utilized per liter of liquid waste volume (mg/l) or in milligrams of oxygen per kilogram of waste solution (mg/kg = ppm = parts per million parts).

Biological stabilization.--Reduction in the next energy level, and the tendency to putrefy, of organic matter as a result of the metabolic activity of organisms.

Biological treatment.--Organic waste treatment in which bacterial and/or biochemical action is intensified under controlled conditions.

C/N (carbon-nitrogen) ratio.--The weight ratio of organic carbon to total nitrogen in a soil or in organic material. A C/N ratio of about 20 or less in waste material is desirable to prevent depression of crop yields by competition of micro-organisms with crops for nitrogen.

Chemical oxidation.--Oxidation of organic substances without benefit of living organisms. Examples are by thermal combustion or by oxidizing agents such as chlorine.

COD (Chemical Oxygen Demand).--An indirect measure of the biochemical load exerted on the oxygen content of a body of water when organic wastes are introduced into the water. It is determined by the amount of potassium dichromate consumed in a boiling mixture of chromic and sulfuric acids. The amount of oxidizable organic matter is proportional to the potassium dichromate consumed. If the wastes contain only readily available organic bacterial food and no toxic matter, the COD values can be correlated with BOD values obtained from the same wastes.

Composting.--Present-day composting is the aerobic, thermophilic decomposition of organic waste to relatively stable humus. Humus with no more than 25 percent dead or living organisms is stable enough not to reheat or cause odor or fly problems. It can undergo further, slower decay. In composting, mixing and aeration are provided to maintain aerobic conditions and permit adequate heat development. The decomposition is done by aerobic organisms, primarily bacteria, actinomycetes, and fungi.

Contamination.--A general term signifying the introduction into water of micro-organisms, chemical, organic, or inorganic wastes, or sewage, which renders the water unfit for its intended use.

Dehydration.--The chemical or physical process whereby water in either chemical or physical combination is removed from other matter.

Denitrification.--The process by which nitrates or nitrites in the soil or organic deposits are reduced to ammonia or free nitrogen by bacterial action.

Digestion.--Though aerobic digestion is being used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into compounds that are more simple or biologically stable, or both. Organic matter is decomposed to soluble

organic acids or alcohols and then converted to gases such as methane and carbon dioxide. Complete destruction of organic solid materials by bacterial action alone is never accomplished.

Dissolved oxygen.--The oxygen dissolved in sewage, water, or other liquid and usually expressed as milligrams per liter or as percent of saturation.

Effluent.--A liquid that flows from a containing space.

Evaporation rate.--The quantity of water that is evaporated from a specified surface per unit of time, generally expressed in inches or centimeters per day, month, or year.

Facultative bacteria.--Bacteria that can exist and reproduce under aerobic or anaerobic conditions.

Facultative decomposition.--Reduction of the net energy level of organic matter by facultative micro-organisms.

Fertilizer value.--The worth of plant nutrients contained in wastes and available to plants when the waste is applied to soil. A monetary value assigned to a quantity of organic waste represents the cost of obtaining the same type and amount of plant nutrients in commercial form. The worth of waste as fertilizer can be estimated only for given soil conditions and other pertinent factors such as land availability, time, and handling.

Filtration.--The process of straining a liquid through a porous medium for the removal of suspended or colloidal material contained in the influent liquid.

Gasification.--The process or processes whereby solid or liquid matter is converted to gases such as carbon dioxide, methane, or ammonia through biological activity.

Holding pond.--An impoundment made by constructing a dam or embankment, by excavation, or a combination thereof, for temporary storage of livestock or other agricultural wastes, waste water, or polluted runoff.

Infiltration rate.--The rate at which water enters the soil. Units are usually inches of water per hour.

Influent.--A liquid that flows into a containing space.

Lagoon.--An impoundment made by constructing an excavated pit, dam, embankment, dike, levee, or combination of these for biological treatment of organic wastes. Lagoons are described by the predominant biological characteristics (aerobic, anaerobic, or facultative), by location (indoor, outdoor), by position in a series (primary, secondary, or other), and by the organic material accepted (sewage, sludge, manure, or other).

Liquefication.--Any of several processes whereby solids are converted to liquids. Suspended solids can be liquefied by the biochemical action of micro-organisms or by the physical-chemical process of dissolving. Liquefication as a term is often applied to the operation whereby water or agitation, or both, are used to convert semisolid manure into thick slurries or thinner solid suspensions.

Liquid manure.--A suspension of livestock manure in water in which the concentration of manure solids is low enough that flow characteristics of the mixture are more like those of Newtonian fluids than of plastic fluids. Synonymous with slurry.

Manure flume or gutter.--Any restricted passageway, open along its full length to the atmosphere, through which liquid moves by gravity.

Manure pit.--A storage unit in which accumulations of manure are collected before treatment or disposal. Water may be added in the pit to promote liquefication.
Organic content.--Synonymous with volatile solids except for traces of inorganic materials such as calcium carbonate that lose weight at temperatures used in determining volatile solids.
Oxidation.--Combining of oxygen with organic waste to produce simple chemical compounds such as carbon dioxide, water, nitrates, etc.
Oxidation ditch.--A shallow and continuous ditch, often oval in shape, around which liquid wastes are circulated by rotors or propellers which also transfer oxygen from the atmosphere for aerobic treatment.
Oxidation lagoon or pond.--Synonymous with aerobic lagoon.
pH.--The symbol for the logarithm of the reciprocal of hydrogen ion concentration, expressed in moles per liter of a solution and used to indicate an acid or alkaline condition. A pH of 7 indicates neutrality; less than 7 is acid; greater than 7 is alkaline.
Percolation.--The movement of water through soil.
Percolation rate.--The rate, usually expressed as a velocity, at which water moves through saturated granular material.
Pesticide.--A chemical substance used to kill or control pests such as weeds, insects, algae, rodents, and other undesirable agents.
Pollution.--The presence in a body of water (or soil or air) of substances of such character and in such quantities that the natural quality of the body of water (or soil or air) is degraded so as to impair its usefulness or render it offensive to the senses.
Population equivalent.--The comparison of a given waste load with the calculated human population that normally contributes the same amount of BOD per day. A common base is 0.17 pounds (77.2 g) of 5-day BOD per capita per day.
Putrefaction.--A process of decomposition in which, as a consequence of the breakdown of proteins, end products with offensive odor form.
Sedimentation basin or tank.--A basin or tank in which a liquid (water, sewage, liquid manure) containing settleable suspended solids is retained until part of the suspended solids settle out by gravity.
Seepage.--The movement of liquid through the ground surface. Influent seepage is movement of liquid from surface bodies of water into the soil. Effluent seepage is discharge of liquid from within the soil to the surface of the soil or to surface waters.
Septic.--A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.
Settleable solids.--Those suspended solids contained in waste water that separate by settling when the carrier liquid is held in a quiescent condition for a specified time interval.
Sludge.--The accumulated settled solids deposited from sewage or other raw or treated wastes in lagoons, basins, or tanks, and containing enough water to form a semiliquid mass.
Suspended solids.--Solids either floating or suspended in water, sewage, or other liquid wastes and that are removable by laboratory filtering.
Total solids.--The residue from water, sewage, other liquids, or semisolid masses when moisture is evaporated and the remainder is dried at a specified temperature (usually 103°C).

Volatile acids.--Organic acids of low molecular weight used as control parameters in anaerobic digestion. A low figure under normal conditions for volatile acids (400-2000 mg/l) indicates that digestion is proceeding satisfactorily.
Volatile solids.--That portion of total or suspended solids driven off as volatile (combustible) gases at a specified temperature and time (usually 600°C for 1 hour).

2. MUNICIPAL WASTE-WATER TREATMENT TERMS

Activated sludge process.--A process of waste treatment by which organic matter in dilute water suspension is biologically degraded. High-rate air diffusion through the liquid promotes growth of bacterial and other zoogleal organisms that act on the organic matter in the presence of dissolved oxygen and produce a sludge floc called activated sludge.
Aeration tank.--A tank in which sludge, sewage, or other liquid waste is aerated.
Chlorination.--The application of chlorine to water or waste water, usually for disinfection but frequently for other biological or chemical results such as control of odor or removal of color.
Coagulation.--The aggregation of colloidal and finely divided suspended solids for faster settling out of solution. Coagulation is effected by biological processes or by the use of chemicals such as lime, alum, or polyelectrolytes.
Coliform bacteria.--Micro-organisms common in the intestinal tracts of man and warm-blooded animals. Coliform bacteria are commonly used as indicators of the possible presence of harmful bacteria.
Combined sewer.--A conduit that carries both sewage and storm-water runoff.
Comminutor.--A device for catching and shredding heavy solid matter in the primary stage of waste treatment.
Diffused air.--A technique by which air under pressure is forced into sewage in an aeration tank. Air is pumped down into the sewage through a pipe and escapes through holes in the side of the pipe.
Distillation.--A process in waste treatment whereby the effluent is heated and the vapor or steam is removed. The steam or vapor returns to a liquid that is almost pure water, and the pollutants remain in the concentrated residue.
Extended aeration process.--A modification of the activated sludge process that provides for aerobic sludge digestion within the aeration system.
Floc.--A clump of solids formed in sewage when certain chemicals are added.
Flocculation.--The process by which certain chemicals added to sewage cause solids to form in clumps that can be removed by sedimentation.
E. coli (Escherichia coli).--One of the species of bacteria in the coliform group. Its presence is indicative of fresh fecal contamination.
Fecal Bacillus coli, fecal coliform.--General terms for those bacteria that have their natural habitat within the intestinal tract of man and beast.

Fecal streptococcus (Streptococcus fecalis).--An a-hemolytic bacterium that brings about dissolution of the red blood cells of higher animals. Enterococci is a general term.

Incineration.--A process by which sludge is burned to remove water and reduce the remaining residues to nonburnable ash.

Ion.--An electrically charged atom or molecule.

Lagoon.--A pond containing raw or partially treated waste water in which aerobic or anaerobic stabilization occurs.

Mechanical aeration.--The introduction of atmospheric oxygen into a liquid by the mechanical action of paddles, paddle wheels, sprays, or turbines.

Microbes.--Minute living things, either plant or animal.

Mixed liquor.--The name given effluent that comes from an aeration tank after sewage is mixed with activated sludge and air.

Molecule.--The smallest particle of an element or compound that can remain in a free state and retain the characteristics of the element or compound.

MPN (Most Probable Number).--A figure expressing a statistical count of the number of micro-organisms within a given volume.

Organic matter.--The waste, of plant or animal origin, from homes or industry.

Oxidation.--The consuming or breaking-down of organic wastes or chemicals in sewage by bacteria or chemical oxidants.

Oxidation pond.--A manmade lake or body of water in which biological oxidation of organic matter is accomplished by natural or mechanical transfer of oxygen from the air to waste water.

Pathogenic bacteria.--Disease-causing bacteria.

Polyelectrolytes.--Synthetic chemicals used to speed the removal of solids from sewage by causing them to coagulate or clump together.

Primary treatment.--The first phase of waste-water treatment. It normally consists of screening and settling out solids.

Secondary treatment.--The treatment of waste water by biological methods after primary treatment.

Sewage.--Water after it has been fouled by various uses. It can be a combination of the liquid or water-carried wastes from residences, business buildings, and institutions together with that from industrial and agricultural establishments. Ground water, surface water, and storm water can also be present.

Sewerage system.--Any system whether community or individually, publicly or privately owned, for the collection and disposal of sewage or liquid industrial wastes, or both. It includes the various devices for the treatment of such sewage or industrial wastes.

Sludge.--The accumulated settled solids deposited from sewage or other raw or treated wastes in tanks or basins, containing enough water to form a semiliquid mass.

Tertiary treatment.--The further treatment of waste water beyond that obtained by secondary treatment.

Trickling-filter process.--A secondary waste treatment process whereby wastes are caused to flow by gravity through an artificial bed of coarse material that utilizes the formation of zoogleal slimes to clarify and oxidize the waste water.

Virus.--An agent or form that is smaller than bacteria and capable of producing infection and diseases in man or other large species.
Zoogleal organisms.--Organisms imbedded in a jellylike matrix or film usually associated with biological processes in sewage treatment facilities.

3. ONSITE SEWAGE DISPOSAL TERMS

Absorption field or drainfield.--A system of open-jointed or perforated pipe or other distribution units of approved type to receive flow from a septic tank and designed to distribute effluent for oxidation and absorption by the soil.
Distribution box.--A receptacle placed between a septic tank and drainfield from which two or more lines of drain tile or perforated pipe may extend to distribute effluent from the septic tank to each line.
Effective capacity.--The liquid volume of a septic tank contained below the liquid-level line.
Effective depth.--The liquid depth of a septic tank measured from the inside bottom up to the invert of the effluent line.
Freeboard or air space.--The distance measured from the liquid-level line up to the inside top of a septic tank.
Grease trap.--A watertight receptacle or reservoir to remove grease from drainage wastes from kitchen or other sources.
House sewer.--A pipe conveying sewage from a house or building to a street sewer or a septic tank or other treatment unit.
Individual sewage disposal system.--A system of piping, tanks or treatment devices, and subsurface absorption field for handling and disposing of sewage.
Percolation test.--A determination of the rate of percolation or seepage of water through natural soils expressed as time in minutes for a 1-inch fall of water in a test hole.
Septic tank.--A watertight tank or receptacle used as a reservoir for receiving or disposing of sewage wastes. Septic tanks work on three principles:

a. Sedimentation, which removes some of the settleable solids, forming sludge.
b. Flotation, which removes some of the fat and greases from the waste water, forming scum.
c. Anaerobic biological decomposition.

Septic tank system.--A complete system consisting of house sewer, septic tank, and soil absorption field.
Sewage.--Human and domestic wastes, liquids, or matter from plumbing fixtures usually carried off by drains and sewers. It includes bath and toilet wastes, laundry wastes, kitchen wastes, and other similar wastes from household appurtenances.

4. SOLID WASTE DISPOSAL TERMS

Aquifer.--A porous, water-bearing geological formation. Generally restricted to materials capable of yielding an appreciable supply of water.

Bulky waste.--Large items of refuse such as appliances, furniture, large auto parts, trees and branches, palm fronds, stumps, flotage, etc.

Cell.--Compacted refuse completely enveloped by soil or cover material.

Commercial refuse.--All solid wastes that originate in businesses operated for profit, such as office buildings, stores, markets, theaters, and privately owned hospitals and other institutional buildings.

Composting.--A controlled microbial degradation of organic waste yielding a nuisance-free product of potential value as a soil conditioner.

Construction and demolition wastes.--Waste building materials and rubble resulting from construction and remodeling and repair and demolition operations on houses, commercial buildings, pavements, and other structures.

Containers, storage (reusable, individual).--Receptacles for garbage and rubbish. Garbage containers should be watertight, have tight-fitting covers, and be easy to clean. Rubbish containers should be such that contents cannot leak through openings or be blown from the top.

Disposal area.--A site, location, tract of land, area, building, structure, or premises used or intended to be used for partial and/or total refuse disposal.

Domestic refuse.--Solid wastes normally originating in residential households or apartment houses.

Garbage.--Animal and vegetable wastes resulting from the handling, preparation, cooking, and serving of foods.

Garbage grinding.--A method of mechanically reducing food waste or garbage and placing the reduced product in sewer systems.

Hazardous wastes.--Wastes that are potentially dangerous, including, but not being limited to, explosives, pathological wastes, radioactive materials, and chemicals.

Hog feeding.--A recycling process by which the food waste or garbage portion of refuse is disposed of by feeding to hogs. Most state regulations either prohibit the practice or require that garbage be boiled a specified time before it is fed.

Incineration.--The process of burning solid, semisolid, or gaseous combustible wastes to an inoffensive gas and a sterile residue with little or no remaining combustible material.

Junk.--A collection of secondary materials, sorted but unprocessed.

Leachate.--Liquid emanating from a land disposal cell that contains dissolved, suspended, and/or microbial contaminants from the solid waste. Leachates from solid waste disposal areas can contaminate surface or underground water.

Offal.--Intestines and discarded parts from the slaughter of animals.

Onfarm sanitary landfill.--A trench or excavation constructed to safely dispose of onfarm solid wastes by spreading, compacting in thin layers, and covering with compacted earth at the end of each operating day.

Open dumps.--The accumulation of waste from one or more sources at a central disposal site with little or no management.

Particulate matter.--Any liquid or solid so finely divided as to be capable of being wind-blown or suspended in air or gas.

Pathogen.--A disease-producing organism.

Putrescible.--Capable of being so rapidly decomposed by micro-organisms as to cause nuisances from odors, gases, etc.

Refuse.--Putrescible and nonputrescible solid wastes, except body wastes, including garbage, rubbish, ashes, incinerator ash, incinerator residue, street cleanings, and solid market and industrial wastes.

Salvaging.--The controlled removal of reusable materials from an open dump or landfill.

Sanitary landfill.--A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, but utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary.

Scavenging.--The uncontrolled removal of discarded materials, usually from an open dump.

Sewage treatment residues.--Coarse screenings, grit, and dewatered or air-dried sludge from sewage treatment plants, and pumpings of cesspool or septic-tank sludges, usually disposed of with municipal solid wastes.

Vector (of disease).--A living insect or other arthropod or animal (not human) that transmits infectious diseases from one person or animal to another.

Waste.--Useless, unwanted, or discarded material resulting from normal community activities. Wastes include solids, liquids, and gases. Solid wastes are classed as refuse.

Working face.--That portion of a sanitary landfill where waste is discharged, spread, and compacted before the daily cover is placed.

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